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Earth-Mars Telecommunications and Information Management System (TIMS): Antenna Visibility Determination, Network Simulation, and Management Models

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November 1996

Prepared for
Lewis Research Center
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National Aeronautics and
Space Administration

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ANTENNA VISIBILITY DETERMINATION, NETWORK SIMULATION, AND MANAGEMENT MODELS

RESEARCH REPORT

October 1996

Prepared for:

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ABSTRACT

This report presents the results of our research on Earth-Mars Telecommunications and Information Management System (TIMS) network modeling and unattended network operations. This research is a follow-on study to prior activities reported in the documents referenced in paragraph 1.1. The primary focus of our research is to investigate the feasibility of the TIMS architecture, which links the Earth-based Mars Operations Control Center, Science Data Processing Facility, Mars Network Management Center, and the Deep Space Network of antennae to the relay satellites and other communication network elements based in the Mars region. The investigation was enhanced by developing Build 3 of the TIMS network modeling and simulation model. The results of several "what-if" scenarios are reported along with reports on upgraded antenna visibility determination software and unattended network management prototype.

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ACRONYMS AND ABBREVIATIONS

ACK	Acknowledgement
AM	Agent Manager
ASAP	Artificial Satellite Analysis Program
BONeS	Block-Oriented Network Simulator
CSU	Communications Support Unit
CVDS	Communication Visibility Determination Software
D/L	Downlink
DSN	Deep Space Network
DSU	Data Service Unit
GUI	Graphical User Interface
HPIB	Hewlett Packard Interface Bus
ID	Identification
JPL	Jet Propulsion Laboratory
LAN	Local Area Network
LMO	Low Mars Orbiter
MCH	Mass Communication Hub
MIB	Management Information Base
MRS	Mars Relay Satellite
NACK	No-Acknowledgement
NASA	National Aeronautics and Space Administration
PC	Personal Computer
SAC	Spacecraft Attitude Compass
SNMP	Simplified Network Management Protocol
TIMS	Telecommunications and Information Management System
TT&C	Telemetry, Tracking, and Satellite Commanding
WAN	Wide Area Network

SECTION 1
INTRODUCTION

The purpose of this research is to develop Build 3 of the Telecommunications and Information Management System (TIMS), which consists of Earth-Mars communication network modeling and simulation, and prototyping unattended network operations management for the Mars region. This build extends the work performed in Build 2 by supporting failures in communication links and message acknowledgment and no-acknowledgment (ACK/NACK) in the simulation model. The study also reports extensively on traditional network management processes and provides the background for understanding the level of effort required to implement an operational and complete unattended network management system.

1.1 APPLICABLE DOCUMENTS

a. *Earth-Mars Telecommunication and Information Management System (TIMS): Simulation and Network Management Models*, Loral AeroSys, LAS-TIMS-003, March 1995.

b. *Earth-Mars Telecommunication and Information Management System (TIMS): Simulation and Network Management Models*, Loral AeroSys, LAS-TIMS-002, March 1994.

c. *Earth-Mars Telecommunication and Information Management System (TIMS): An Architecture Definition*, Loral AeroSys, LAS-TIMS-0001, April 1993.

1.2 DOCUMENT ORGANIZATION

This document contains five sections and Appendices A, B, and C.

a. Section 2 of this document describes the upgrade and software conversion efforts for the TIMS communication visibility determination.

b. Section 3 describes TIMS modeling and simulation effort and analysis of simulation output data.

c. Section 4 presents an overview of the conventional satellite network management process and a multi-agent system prototype for an unattended network management node.

d. We present some concluding remarks in Section 5.

e. Appendix A presents a user's guide, input and output files, and variables in the TIMS communication visibility determination software.

f. Appendix B contains additional TIMS simulation outputs and plots of performance parameters.

g. Appendix C contains a listing of the code for the multi-agent system prototype for unattended network operation.

SECTION 2
UPGRADE OF TIMS
COMMUNICATION VISIBILITY DETERMINATION SOFTWARE (CVDS)

The objective of this task is to convert antenna visibility determination software from FORTRAN to the C programming language. Antenna visibility is needed to transmit information between the network elements in the Mars region and the antenna in the Deep Space Network on the Earth surface. Additional details on the programs are reported in Applicable Document a (refer to paragraph 1.1).

The original program was written in FORTRAN by David Carl with several modules ported from Spacecraft Attitude Compass (SAC) written by Mark Holdridge and Jeff Freedman. It was converted to C using the FOR2C conversion utility and modified by Nino Pino and Don Chu to use the Jet Propulsion Laboratory (JPL) Artificial Satellite Analysis Program (ASAP) to generate orbits. Details on running the program, descriptions of the input and output variables, and files are presented in Appendix A.

With a C version of the code now available, and once the scripts for a "Makefile" are generated, it will be easy to generate antenna visibility dynamically to support "what-if" scenarios. The code also supports orbit propagation for use in estimating orbital positions of Low Mars Orbiters (LMO).

The following enhancements will make the code more useful:

a. Develop a "MAKEFILE" to compile under different UNIX systems. The current version can be compiled in Borland or Microsoft C.

b. Develop Doppler shift and high gain antenna models and link margin.

c. Develop the capability to check indirect paths e.g., 1-->3 = 1-->2-->3.

d. Develop codes to support plots of ecliptic plane and field of view in Graphical User Interface (GUI) format.

SECTION 3
EARTH-MARS TIMS NETWORK MODELING AND SIMULATION

The objectives of the network modeling and simulation aspects of this study are the following:

a. Investigate the effect on the network of link/node failures, and explore recovery and preventive strategies.

b. Incorporate message acknowledgment schemes into the simulation model.

c. Collect more detailed statistics at all nodes of the network. Monitor the number of original and duplicate messages lost, and the number of duplicate messages received; then use collected statistics to analyze network performance.

d. Review Kent State University's document on Multiple Access Control Protocols for the Mars Regional Network. Implement two of the protocols and compare results. Model the system to collect other service level information such as the system's availability, response time, and accuracy of messages received.

3.1 NETWORK DESCRIPTION, MODELING, AND COLLECTED STATISTICS

Detailed description of TIMS network, visibility determination, modeling assumptions, packet processing, and input data are available in Applicable Document a (refer to paragraph 1.1). This model is based on the baseline architecture described in that report. The baseline model for the Earth-Mars Communication Network is presented in Figure 3-1. A revised model with the Rover network node that was brought down for 150 seconds after the start of simulation and brought back up is shown in Figure 3-2. Statistics were collected at several nodes marked with the right-angled triangles below the diagram.

Throughput statistics were collected for each node in the network. Statistics on the volume of messages/packets entering and/or leaving each node was collected. In the previous simulation model, throughput was normalized to the capacity of the link between nodes. In this simulation model the throughput is not normalized. This gives a better description of the number of packets flowing through the simulation model at any point in time. The number of messages received at final destination nodes are also counted.

Graphical plots of simulation statistics with the Rover brought up and down are shown in Figures 3-3 through 3-16. In Figures 3-9 through 3-16, the graphs are annotated to explain when the antennae are visible and invisible and when the rover is up and down. Congestion at each node at points in time are shown by the gap between the plots of Throughput In and Throughput Out in Figures 3-6 through 3-16. Additional plots of the simulation performance parameters are presented in Appendix B. Also presented in Appendix B are the matrices for antenna visibility and network routing tables.

3.2 NETWORK ROUTING SCHEMES

A new routing scheme has been added to the TIMS Earth-Mars Network Simulation Model. The old routing scheme employed a fixed routing algorithm. In fixed routing, packets from a given source to a given destination always follow the same routes. Each node downloads the routing table at the network startup time. A routing table provides the routing path for every node in the network. Only the next hop of the message is needed by any node to pass the message on. After the message takes the next hop, it is the next node's responsibility to continue the routing. The routes are never updated unless someone, such as a network administrator, changes the routing table.

The new routing scheme employs an alternate path routing algorithm. In this scheme, an alternate routing path can be used. This new flexibility allows the network to eliminate possible bottlenecks and data loss when a network connection or node breaks down. Each node downloads a routing table at network startup time. This routing table is stored by the node, and a working copy of it is made, called the local routing table. An alternate routing table is also downloaded at network startup time. This table contains all alternate paths in the network. The node then uses the local routing table to route messages. When a connection or node is down, neighboring nodes will re-compute their local routing table, modifying the routes to avoid the faulty node or connection when possible. Any messages that cannot be routed around the faulty node or connection will be buffered until the fault is corrected. When the faulty node or connection is corrected, neighboring nodes will re-compute their routing tables back to the most optimal routing table. Making the local routing tables dynamic adds more flexibility and fault tolerance to the network model.

After reviewing the materials on Multiple Access Control Protocol generated by Kent State University we decided against implementing any of them since the algorithm being used in our simulation model is more robust than those proposed in the report.

3.3 NODE FAILURES AND MESSAGE REROUTING SCHEMES

A message acknowledgment protocol was added to the Earth-Mars Network Simulation Model. When a node receives a network message, an acknowledgment message is sent back to the last hop (sender) node of the network message. Transmitted network messages are buffered until an acknowledgment is received from the receiving node. If an acknowledgment message is not received within a limit of time, the receiver (next hop) node is deemed to have had a fault. The local routing table is then re-computed to allow all possible messages to be routed around the network fault. Any messages for which the final destination is the faulty node are buffered until the fault is resolved. When messages are received from the faulty node, the routing table is then re-computed to allow interactions with the corrected node as before the fault.

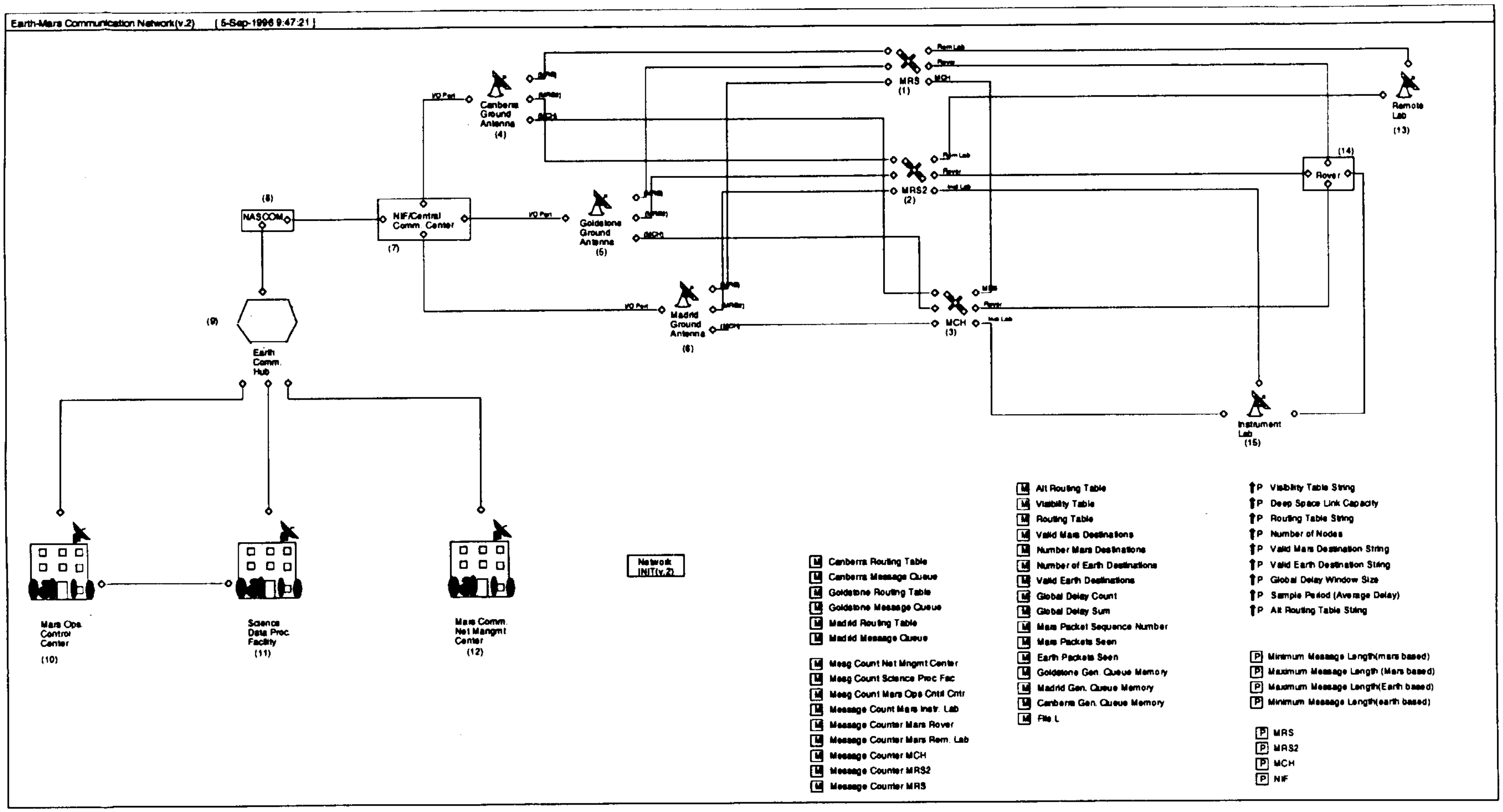

Figure 3-1. Earth-Mars Communication Network Baseline

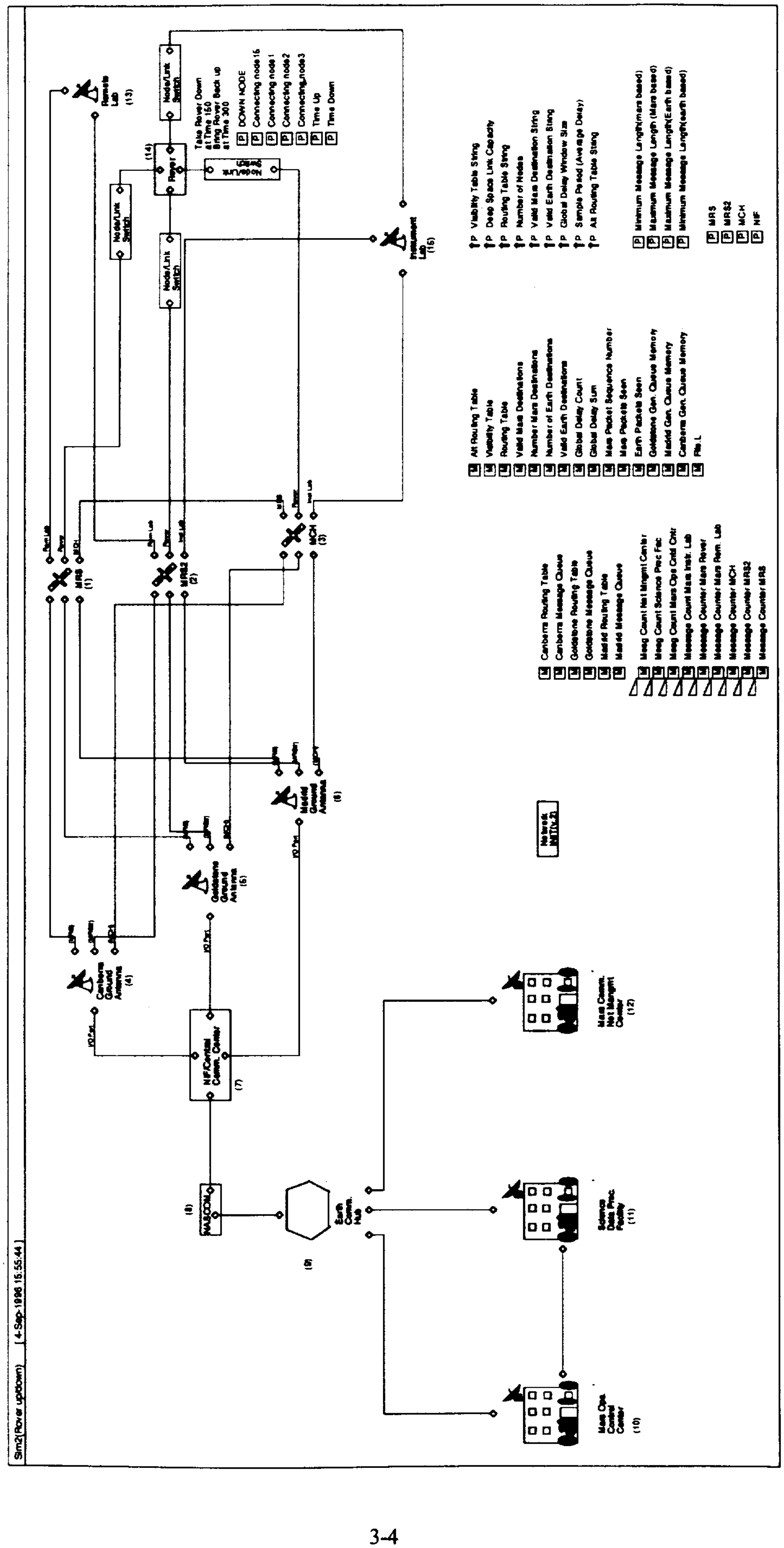

Figure 3-2. Earth-Mars Communication Network with Rover Node (14) Down

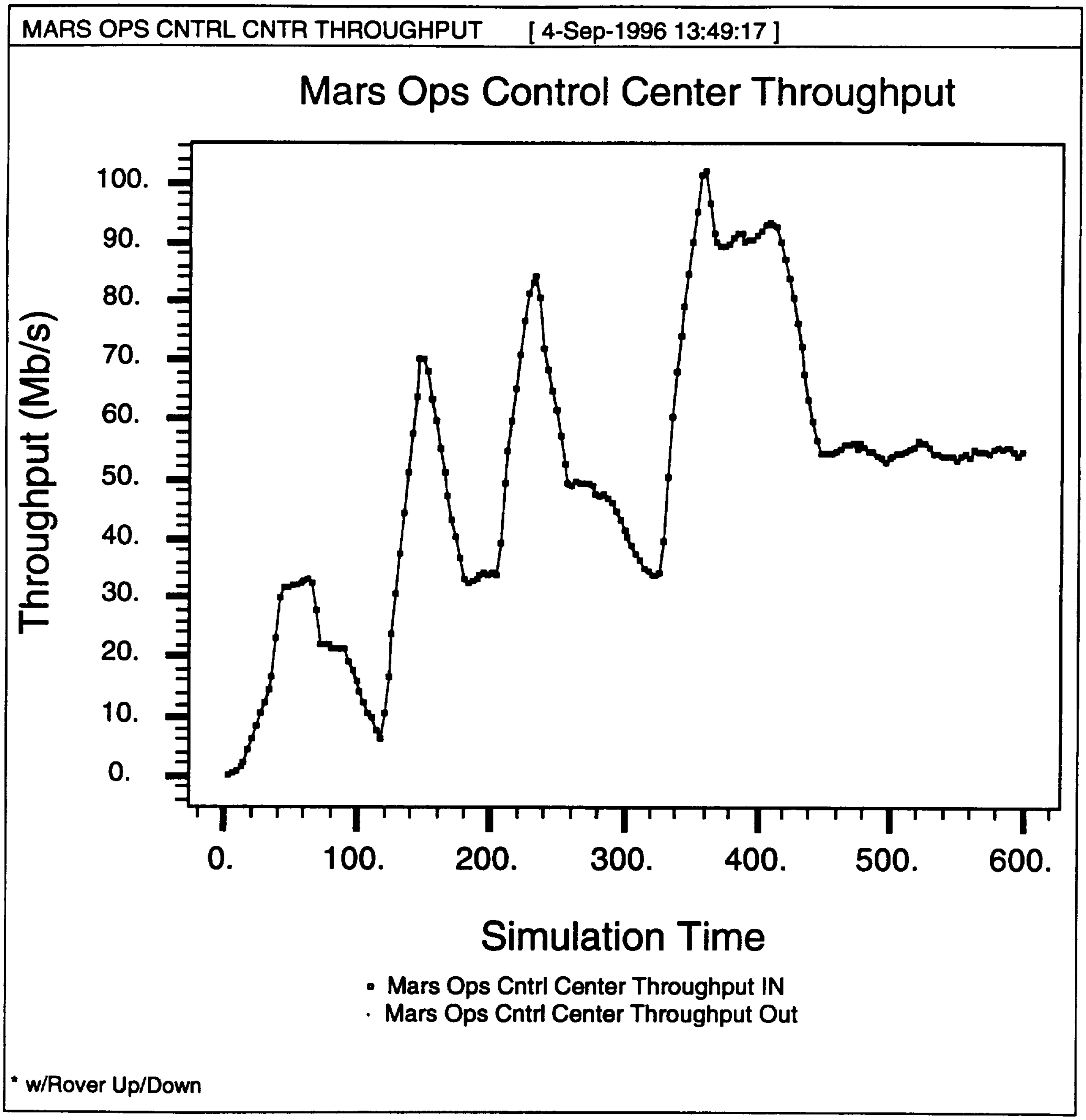

Figure 3-3. Mars Ops Control Center Throughput

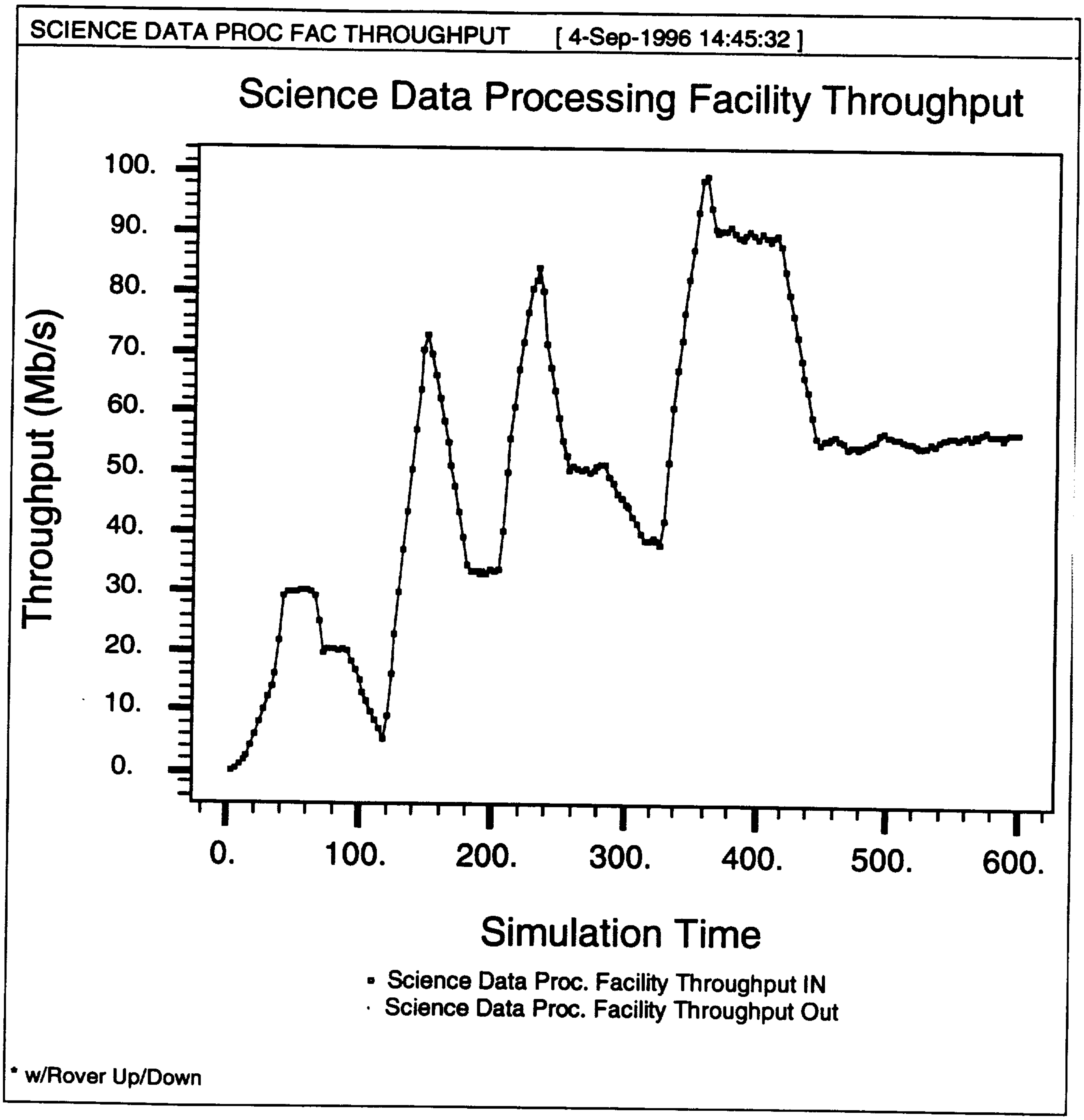

Figure 3-4. Science Data Processing Facility Throughput

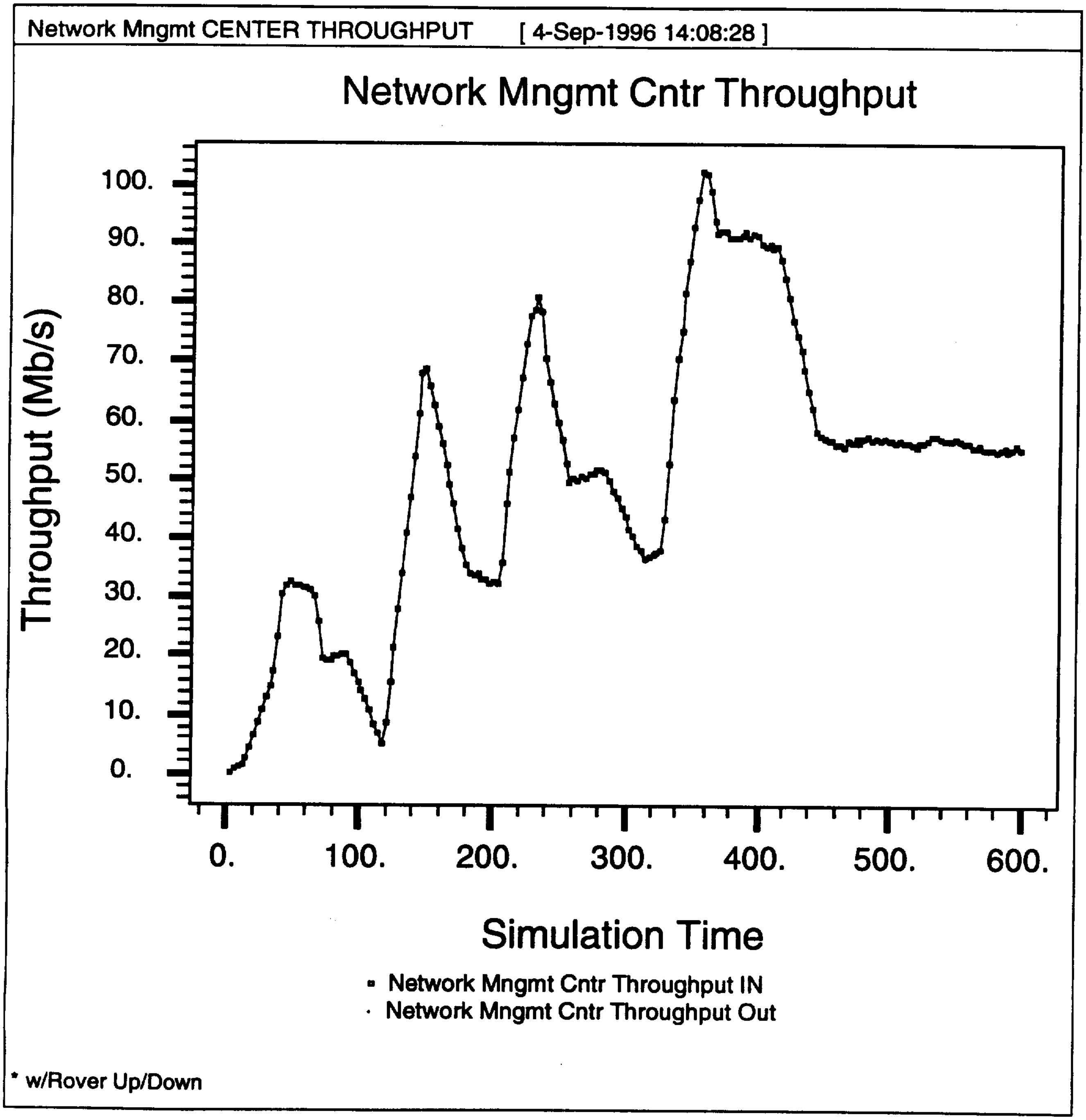

Figure 3-5. Network Management Center Throughput

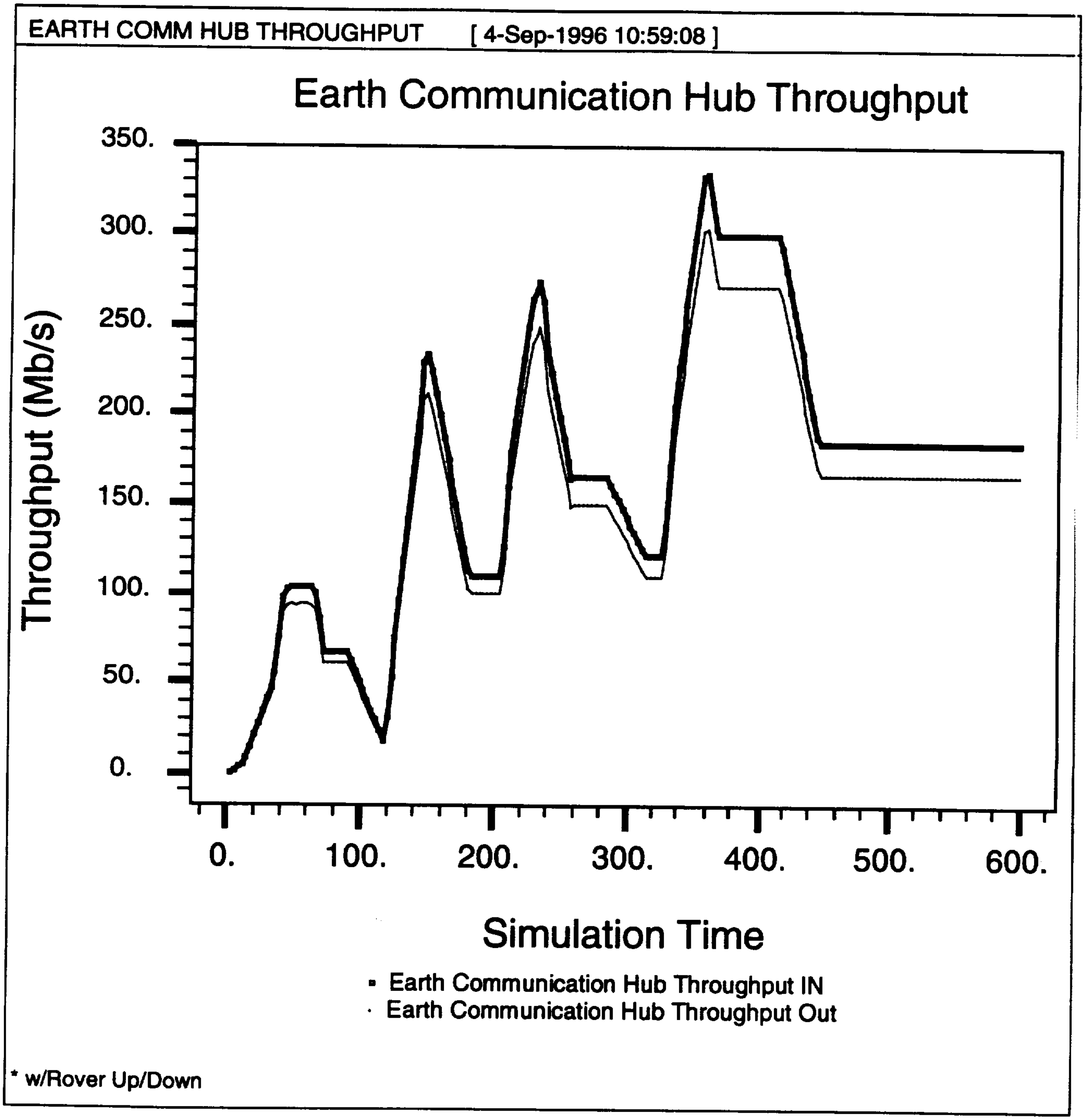

Figure 3-6. Earth Communication Hub Throughput

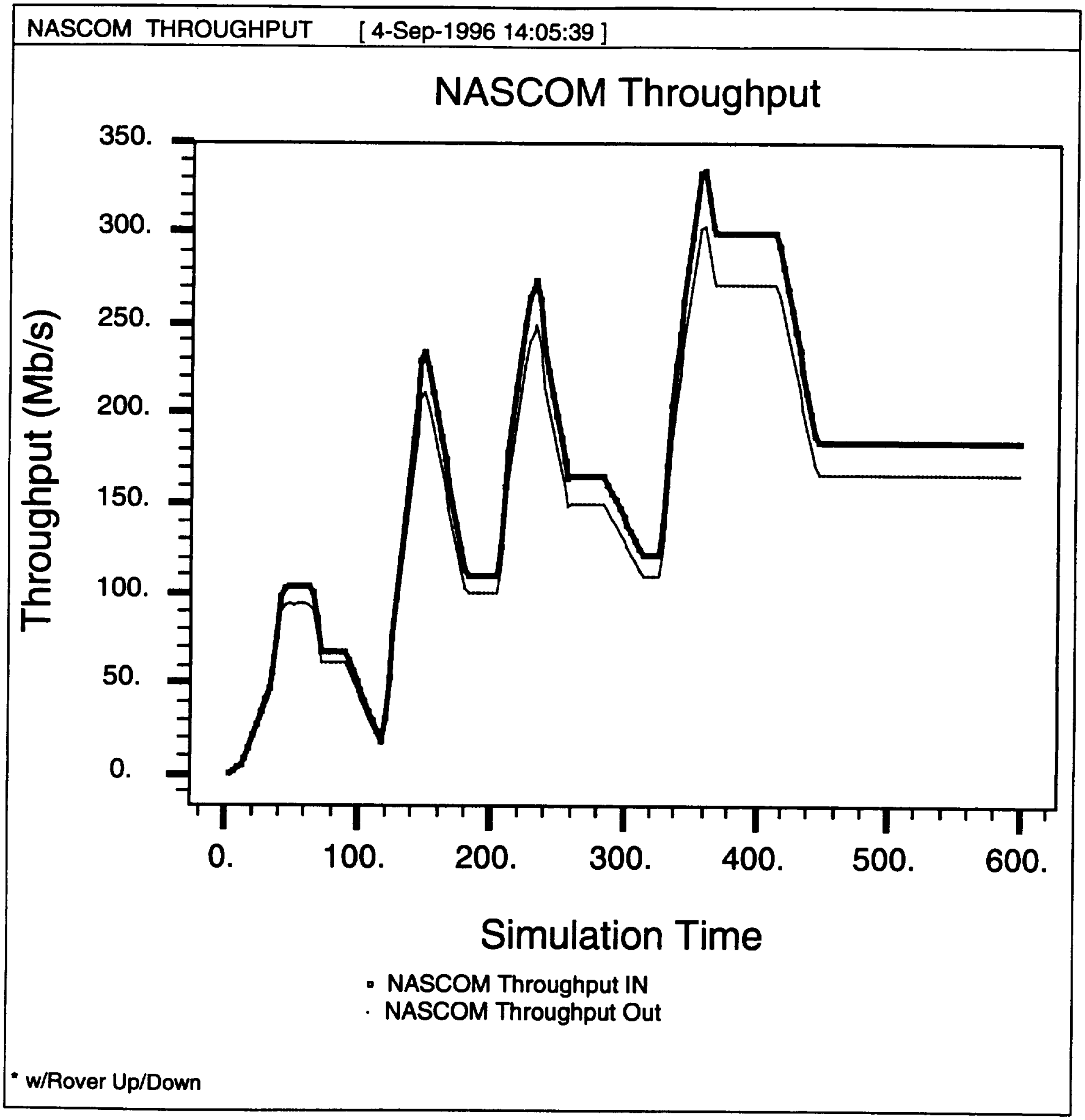

Figure 3-7. Nascom Throughput

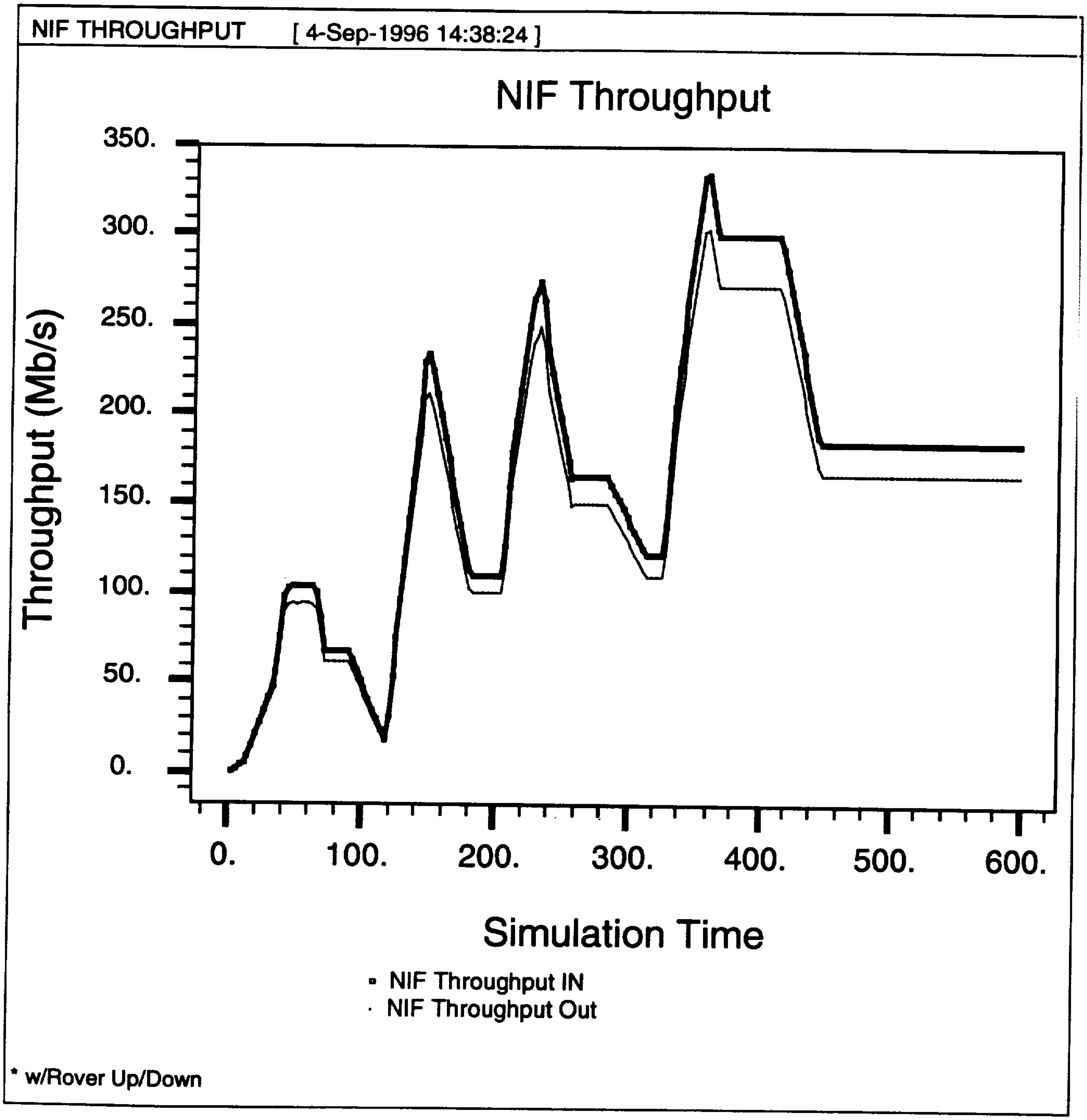

Figure 3-8. NIF Throughput

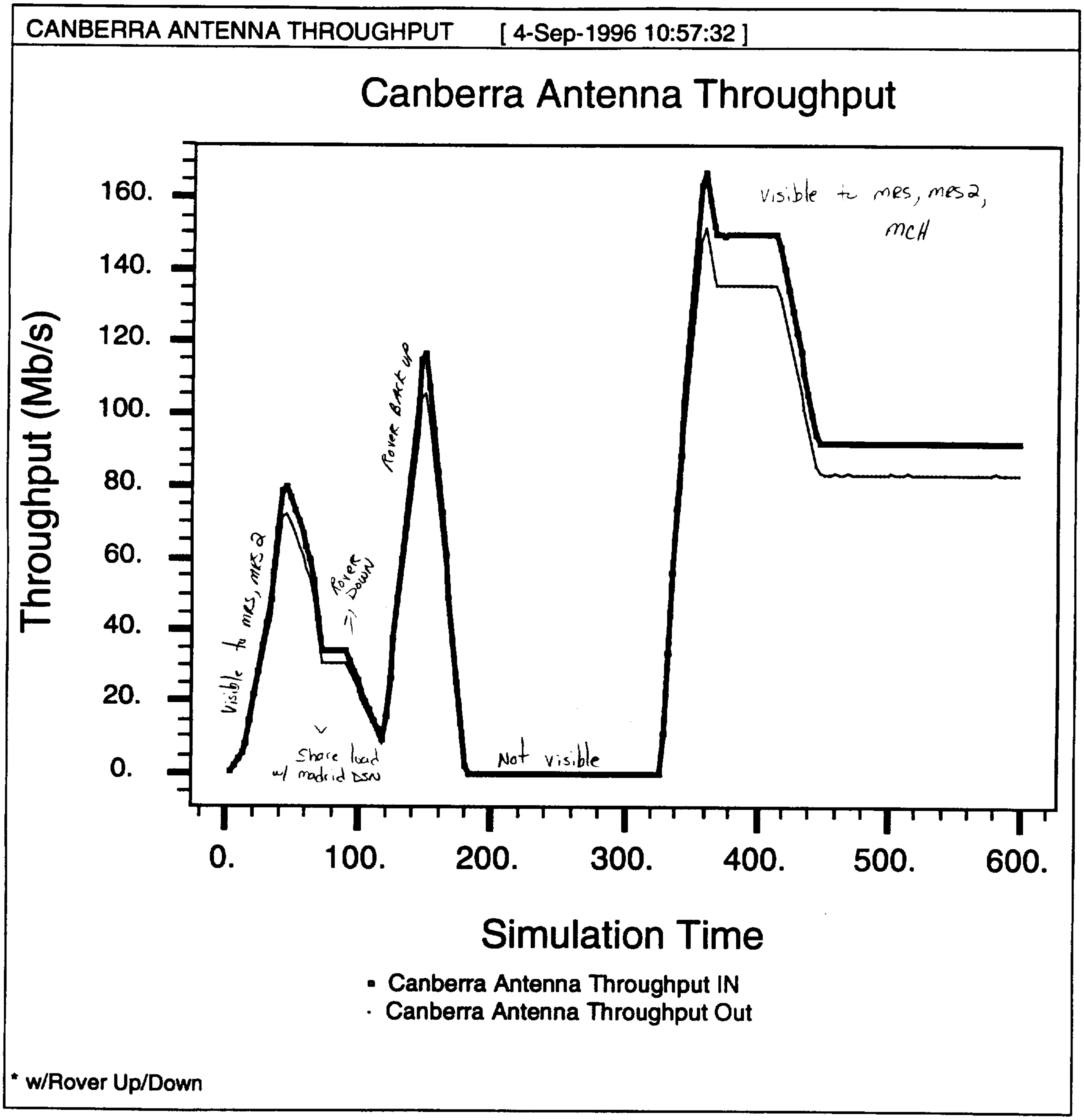

Figure 3-9. Canberra Antenna Throughput

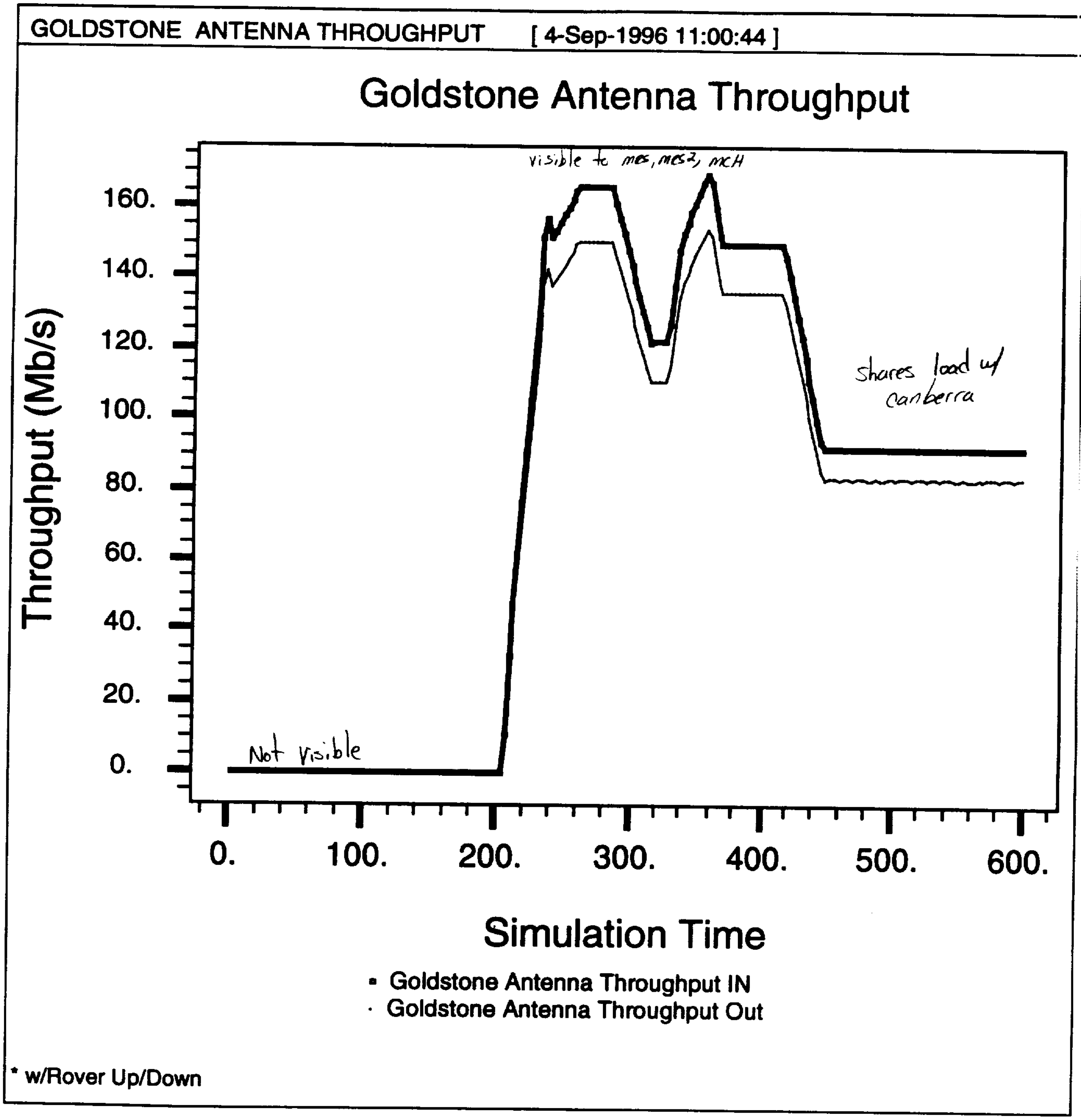

Figure 3-10. Goldstone Antenna Throughput

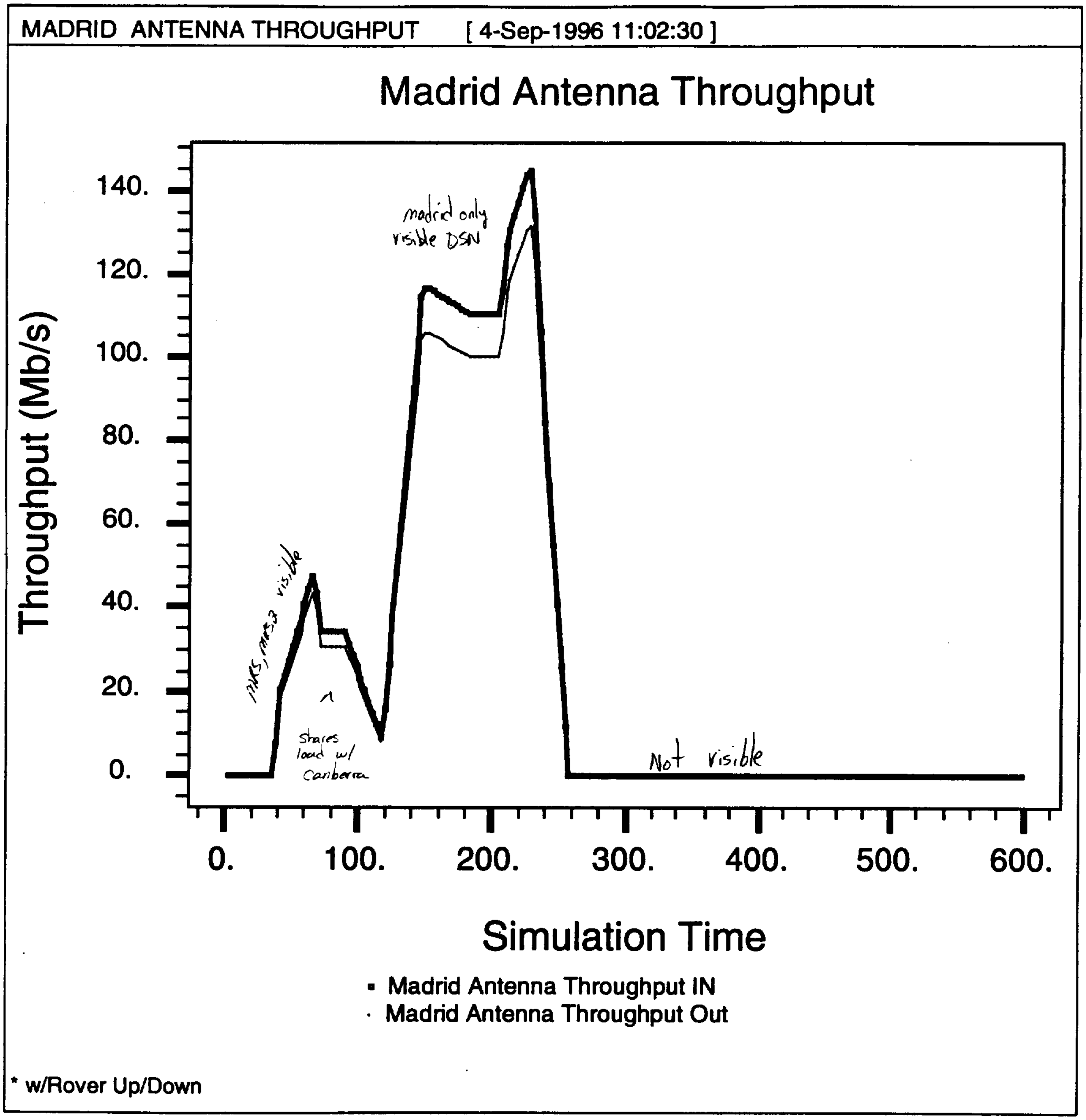

Figure 3-11. Madrid Antenna Throughput

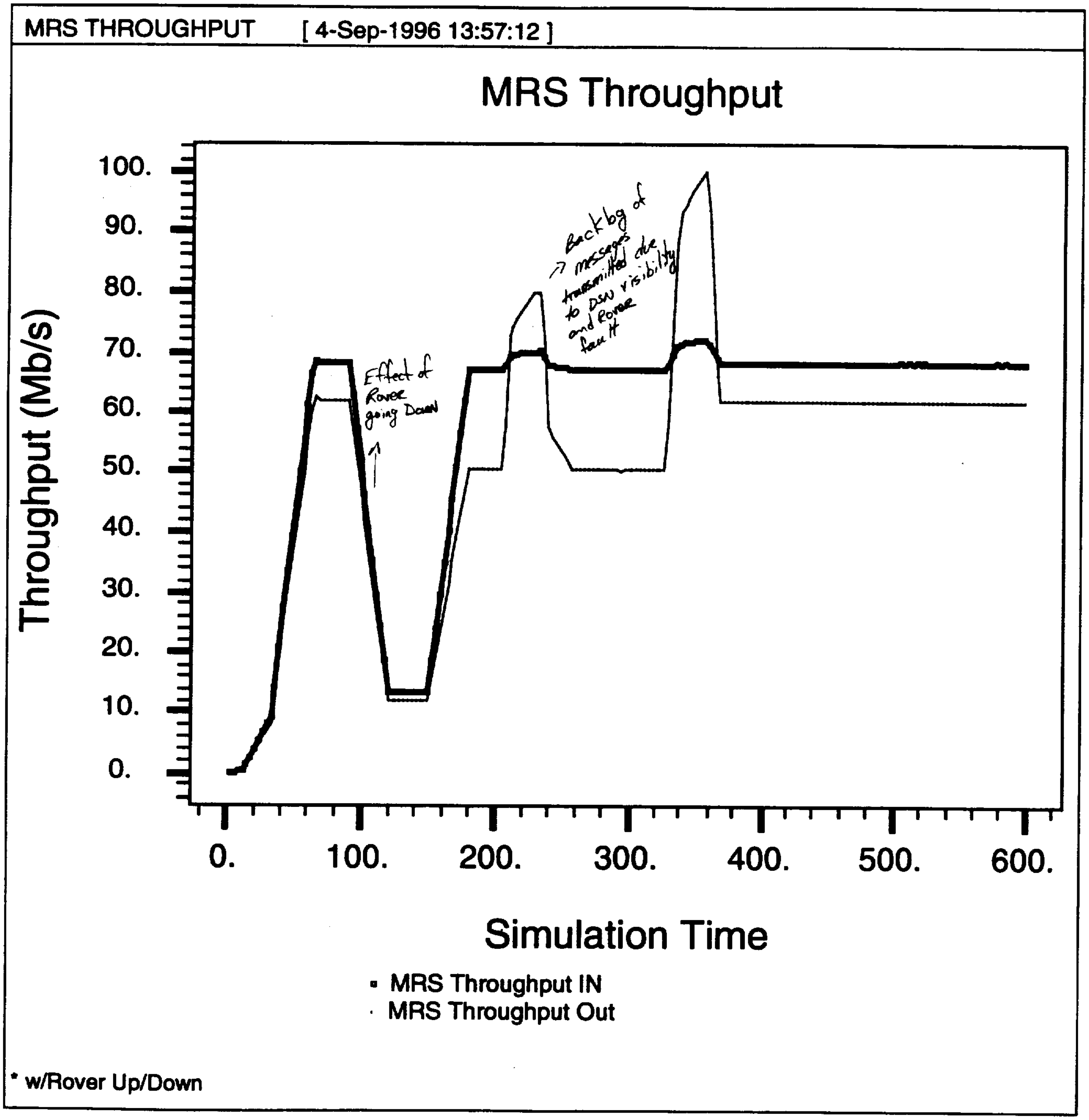

Figure 3-12. MRS Throughput

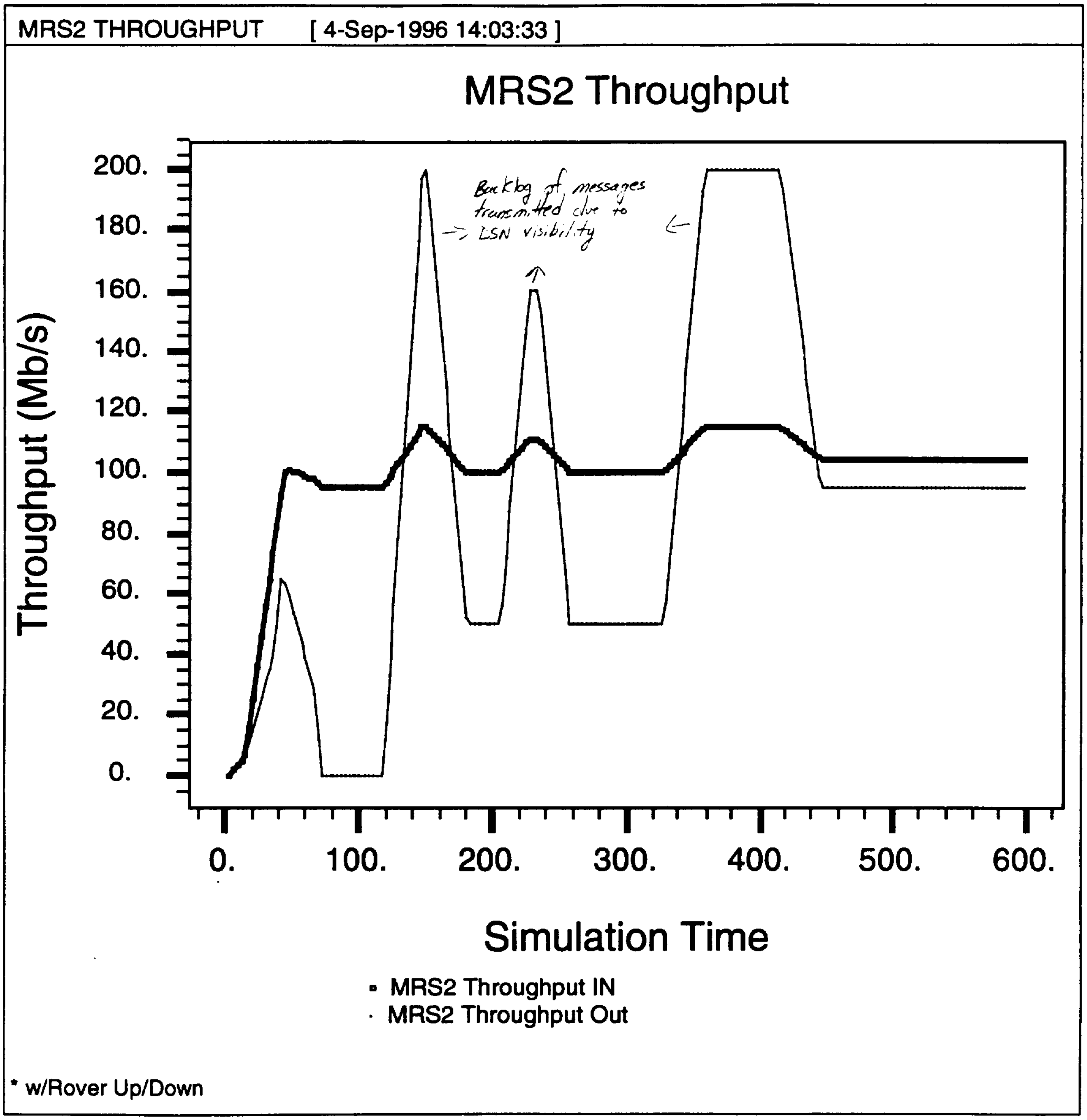

Figure 3-13. MRS2 Throughput

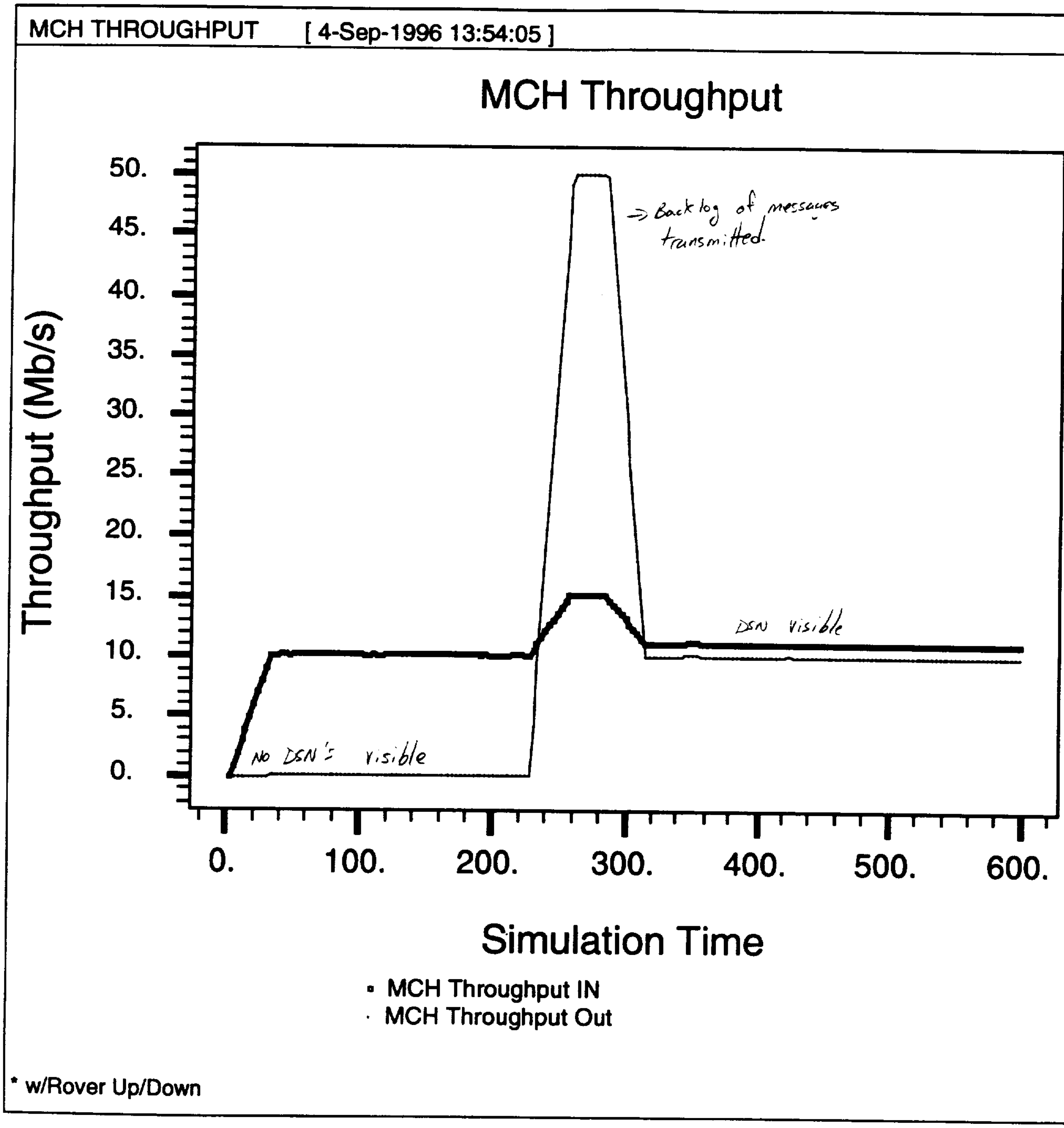

Figure 3-14. MCH Throughput

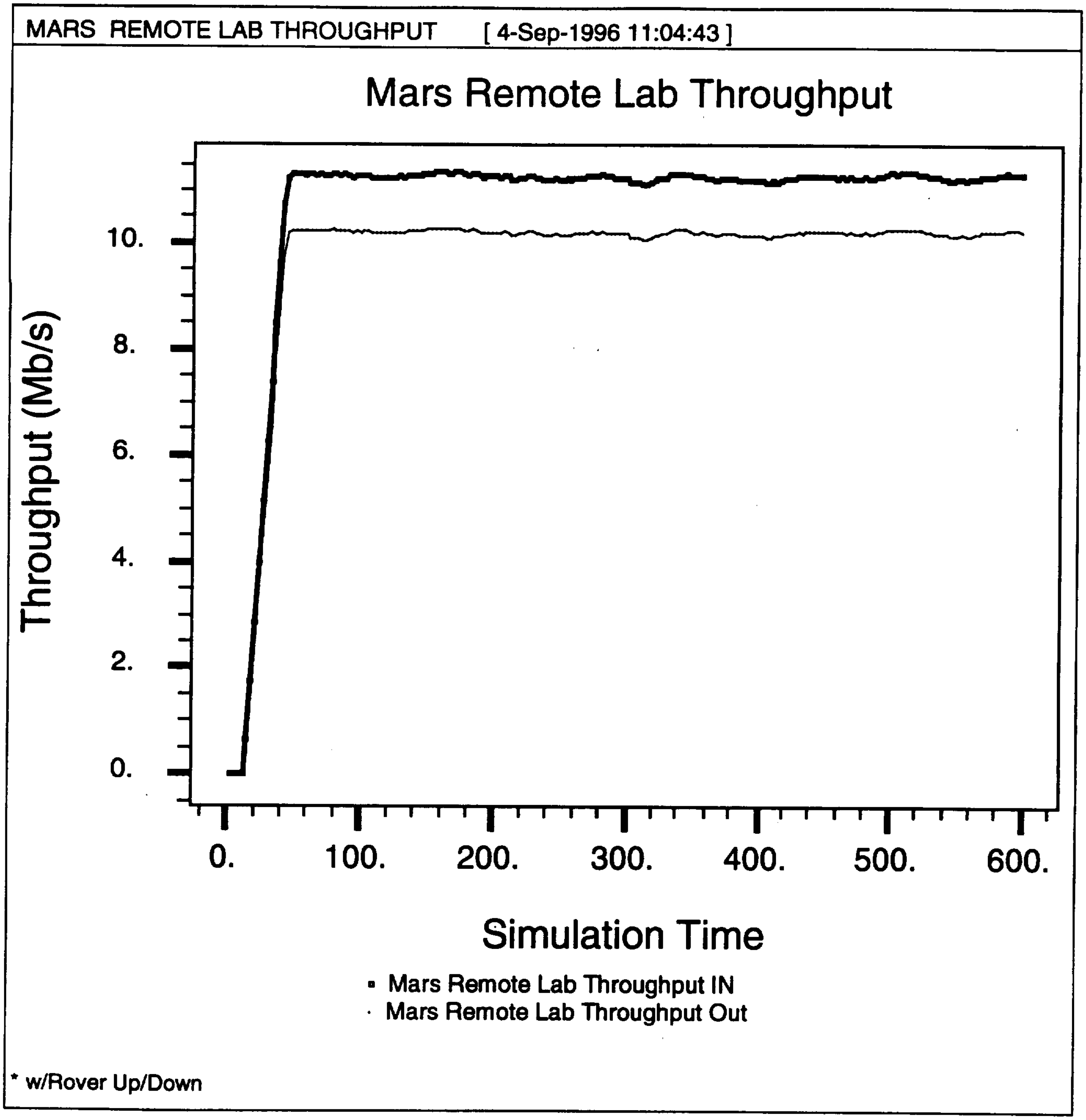

Figure 3-15. Mars Remote Lab Throughput

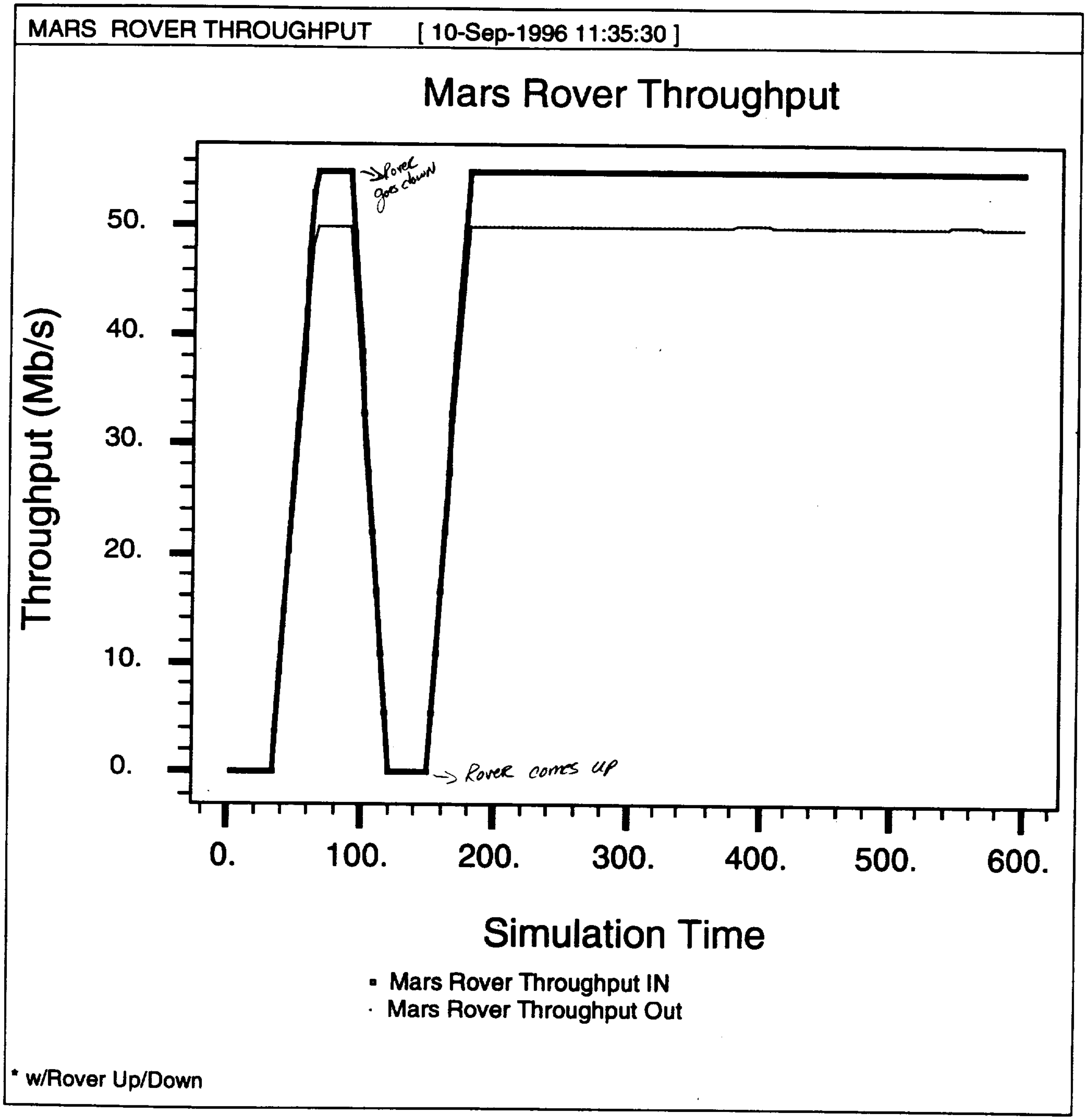

Figure 3-16. Mars Rover Throughput

SECTION 4
EARTH-MARS TIMS - UNATTENDED NETWORK MANAGEMENT

Three objectives of the TIMS unattended network management subtask are the following:

a. Gather and document data on fault classes, i.e., faults caused by failures in computing equipment, communication equipment, and errors in the information transmitted and their causes.

b. Revisit and modify TIMS network management architecture and incorporate knowledge gained since the architecture was developed.

c. Develop a prototype of the architecture to demonstrate high level capabilities of the agents to support network management functions.

In the paragraphs that follow, we present research results aimed at meeting these three objectives. To support unattended network operations we found it necessary to revisit and document conventional approaches used to manage faults in satellite ground and space communications elements. We revisited and modified the TIMS network management architecture and developed a multi-agent prototype for the primary Mars Relay Satellite and its interfaces with other network elements.

4.1 CONVENTIONAL APPROACHES FOR MANAGING COMMUNICATION NETWORK ELEMENTS

Traditional network managers employ tools that provide the user with a bird's eye view of the network. The user can view the network from a global or component perspective as shown in Figure 4-1. Typical displays used to manage network functions (i.e., configuration, fault, security, performance management, and network usage) are depicted in Figure 4-2. An operator monitors the displays and takes appropriate corrective action. Shown in Figure 4-3 are the characteristics of managed objects and network information stored in a global database and made accessible to other network management modules.

A sample of network problem ticketing processing is shown in Figure 4-4. In the event of a fault, a network problem ticket with problem priority, ticket identification number, etc. is generated and routed through the system to responsible personnel for resolution. Each contributing technician completes specific fields in the problem ticket after contributing to the solution of the problem and forwards it to the next technician. Maintenance tickets, installation requests, and upgrade notices are processed in a similar fashion.

A definition of an architecture for managing the faults in the system and interfaces with other network management functions is presented in Figure 4-5. Fault management covers fault detection, identification (i.e., diagnosis), and correction. The fault management process is annotated by the arrows connecting the different elements of the process.

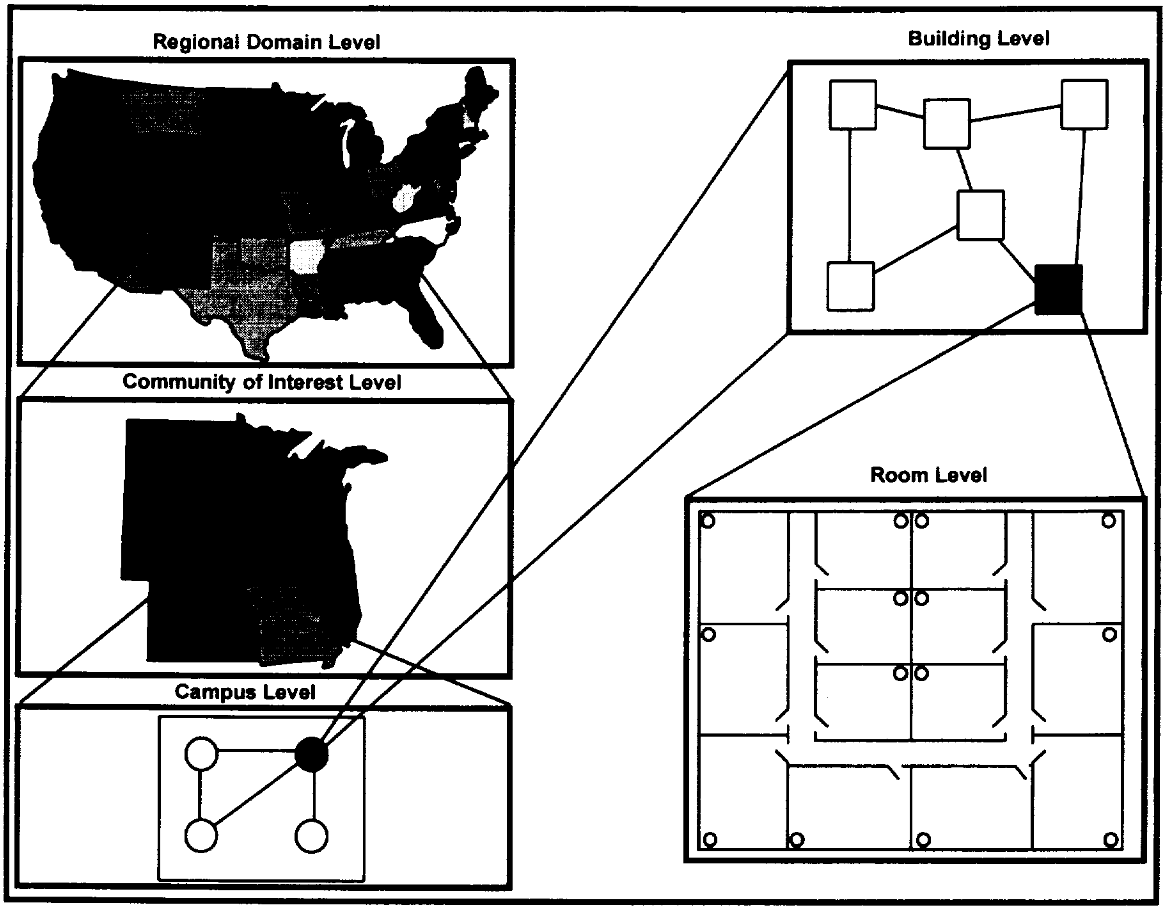

Figure 4-1. Hierarchically Nested Views of the Physical Domain in a Configuration Management Toolset

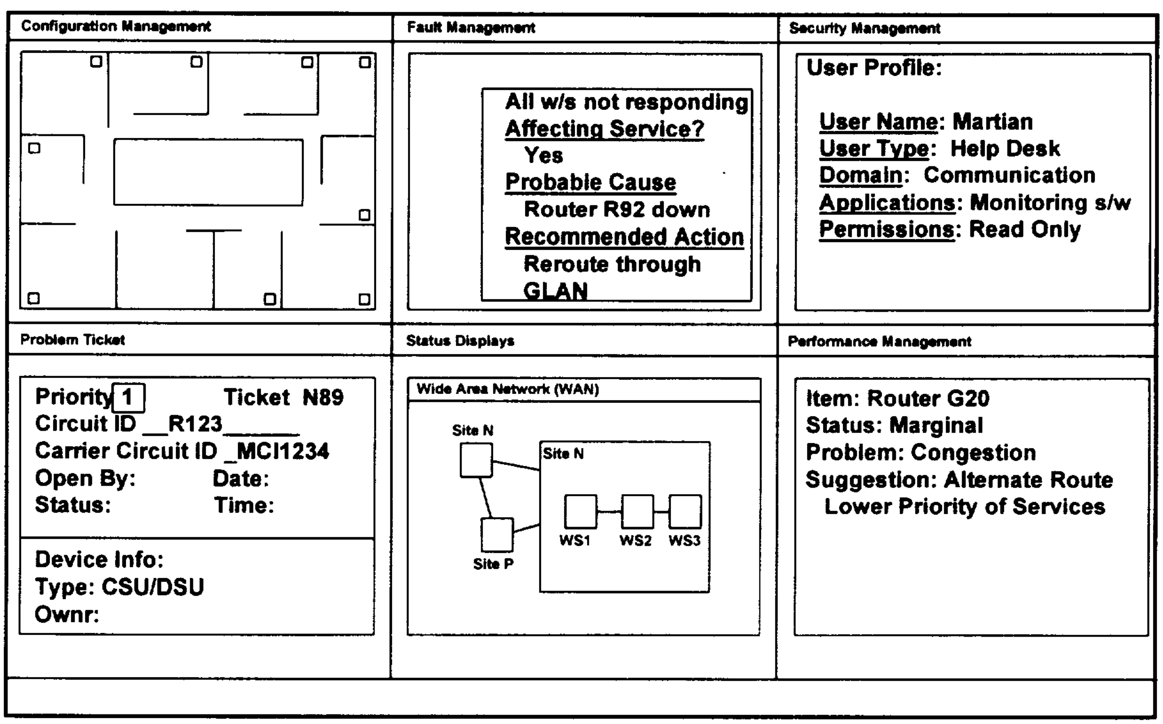

Figure 4-2. Network Management Displays

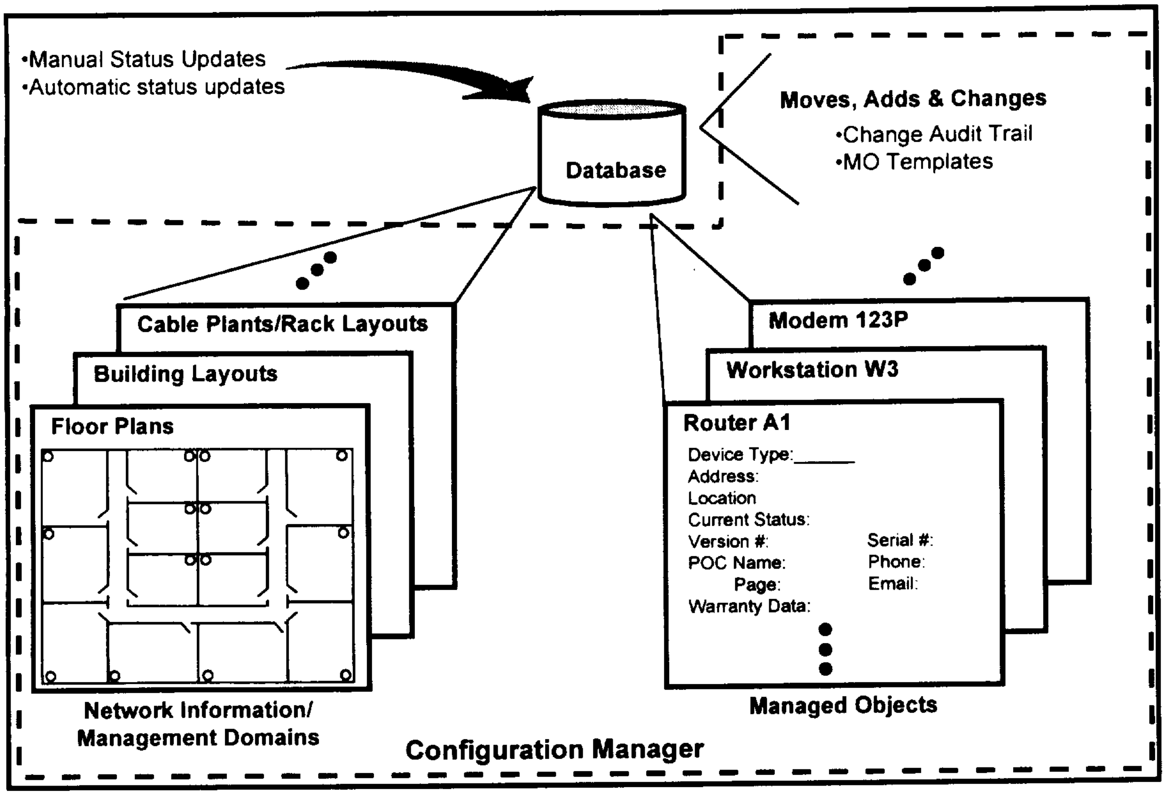

Figure 4-3. Configuration Management Functionality

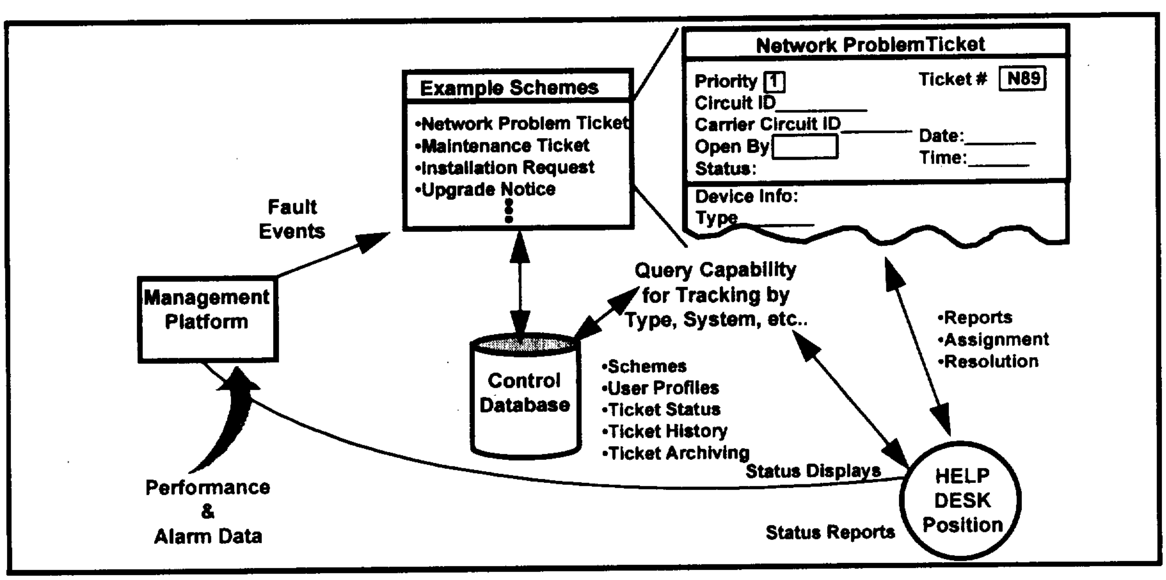

Figure 4-4. Problem Tracking Processing

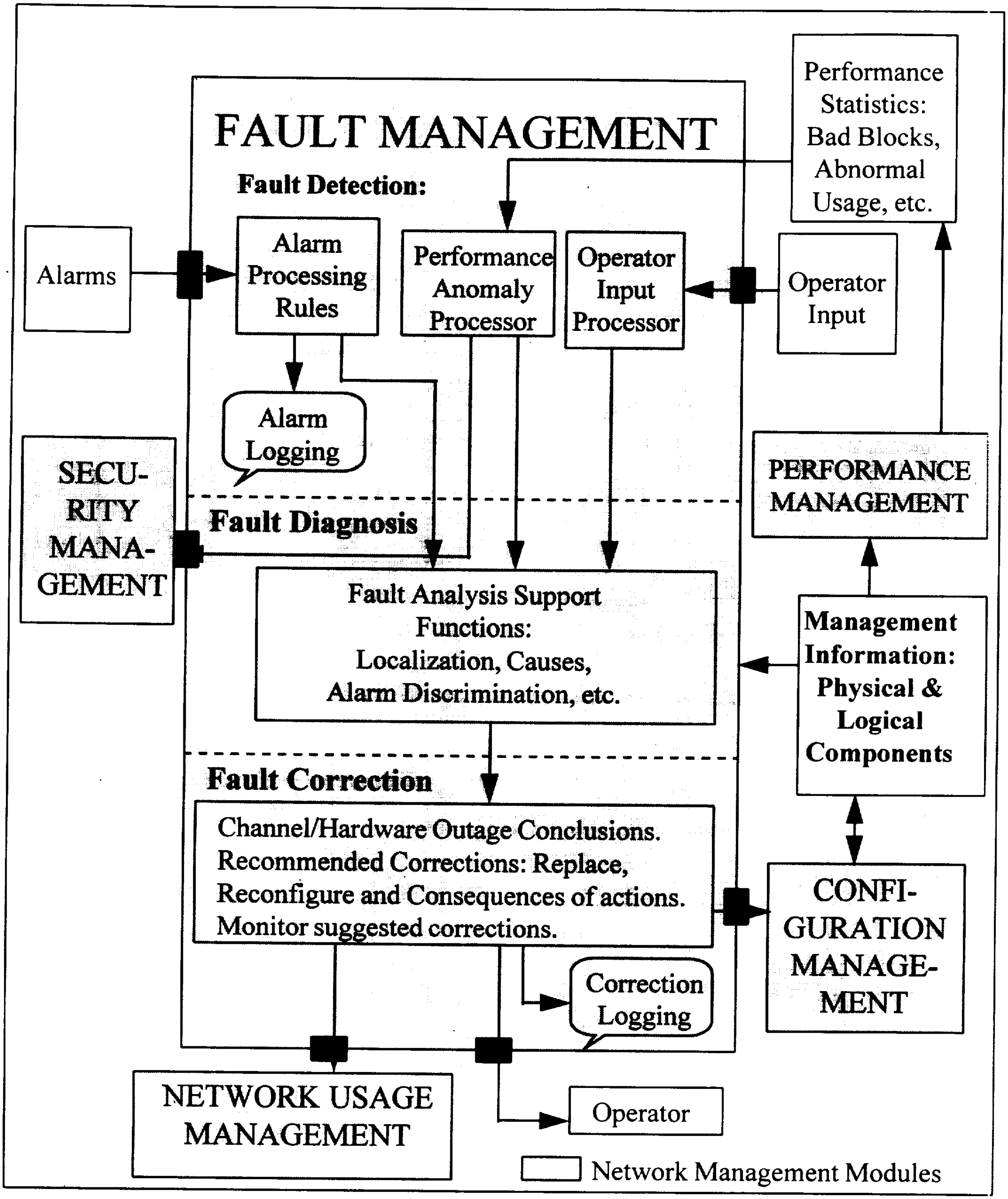

Figure 4-5. Interfaces Between Fault Management and Other Network Management Modules

4.2 CATEGORIES OF FAULTS IN COMMUNICATION NETWORKS

Typical fault categories in network components and possible solution approaches are presented in Table 4-1. Communication devices to be managed in a satellite ground control network are presented in Table 4-2.

Table 4-1. Network Fault Categories and Solution Strategies

DEVICE TYPE	FAULT CATEGORY	POSSIBLE SOLUTION STRATEGY
Servers	Congestion, Crashing	Frequent Backups based on criticality
Concentrators/Hubs	Dropped Packets	Increase bus bandwidth to reduce collisions
Routers/Gateways	Corrupted routing table	Reload or fix routing tables
Bridges/Switches	Overloading, Loss of Links	Filter volume of information flowing through the device
Firewalls	Security Violations	Upgrade Security procedures
Network Interface Cards	Improper Configuration	Fix Configuration
PBXs	Loss of Connection	Fix links
Channel Banks	RF Interference, Loss of Links	Adjust antenna to reduce RF interference
CSUs/DSUs	Noisy Line	Monitor signals
Multiplexes	Bad Data Blocks	Test and fix device
Modems	Bad Configuration or Noisy Line	Reconfigure device
Protocol Monitors	Invalid Displays	Fix or tune device
Video Devices	Poor Displays	Fix or tune device

A network fault management process is depicted in Figure 4-6. Network performance parameters are obtained from the simulator, stored in the database, and used to evaluate faults in the system.

4.3 OVERVIEW OF TIMS UNATTENDED NETWORK MANAGEMENT

The TIMS Unattended Network comprises six nodes: MCH/MRS-Primary (MRS), MCH/MRS-Backup (MRS2), Mars Habitat, Instrument Laboratory, Remote Laboratory, and Rover. These nodes have been described in the various documents listed in paragraph 1.1, as have their relationships and ability to communicate. Thus, this document describes primarily the general structure of the nodes themselves. The architecture of a typical node is presented in Figure 4-7.

Each node has six autonomous agents that handle the five duties described in paragraph 3.2 of the TIMS 1995 Follow-On report (Applicable Document a, see paragraph 1.1). These duties are fault management, network usage, security management, configuration management, and performance management. There is a different agent assigned to each of these tasks. The sixth agent is the Agent Manager (AM). The AM is responsible for coordinating the work done by the other five agents. The AM also serves as the interface between the five agents and the node's Local Coordinator, whose job, in part, is to be the only interface to the AM. When the AM accepts a task from the Local Coordinator, the AM notifies the appropriate agent that the AM has something for it to do. After the appropriate agent completes its portion of the task, the AM decides if the task must be forwarded to another agent, or if the task has been completed. If the task has been completed, the AM notifies the Local Coordinator. However, if more work remains, the task is passed to the appropriate agent for processing. This cycle continues until the task has been completed.

Table 4-2. Devices at Typical Telemetry, Tracking, and Satellite Commanding (TT&C) Sites

DEVICE	RMT. CTL. OR MONITORING TOOLS	REDUNDANCY
UPLINK DEVICES:		
C-band RF switch	HPIB	Spare ch.
K-band RF switch	HPIB	Spare ch.
TTC RF switch	HPIB	No
C- BAND U/C (FPA)	HPIB	N:1
K-BAND U/C	HPIB	N:1
C- BAND U/C (LMA)	Dry contact	N:1
FM MODULATOR	HPIB	N:1
U/L BB MATRIX SW.	HPIB	No
CMU/CMC (site)	RS232/LAN	N:1
CMU/RPU	RS232/LAN	No
DOWNLINK DEVICES:		
D/L RF switch	RS232	Spare ch.
SA 930 receiver	RS232	N:1
C-BAND D/C	HPIB	N:1
K-BAND D/C	HPIB	N:1
FM/PM DEMOD.	HPIB	N:1
D/L BB MATRIX SW.	HPIB	No
PSK DEMOD	HPIB	N:1
BIT FRAME SYNC CARD	LAN SNMP or HPIB, RS232	N:1
SITE COMPUTERS:		
ECW, HP9000/745	LAN, SNMP	No
GDN, HP9000/747	LAN	No
IOT, HP9000/715	LAN	Yes
Site admin. PCs	LAN	Yes
OTHER SITE DEVICES:		
AMDS, HP9000/743	LAN	No
LSD (CMU)	LAN	No
LSD (RPU)	LAN	No
LSD (BMU)	LAN	No
CCC COMM. EQUIP:		
TIMPLEX MUX	SNMP	1-to-1
LAN HUB	SNMP	1-to-1
Wellfleet router	SNMP	1-to-1
RF modem	SNMP	N:1
CSU	SNMP	N:1

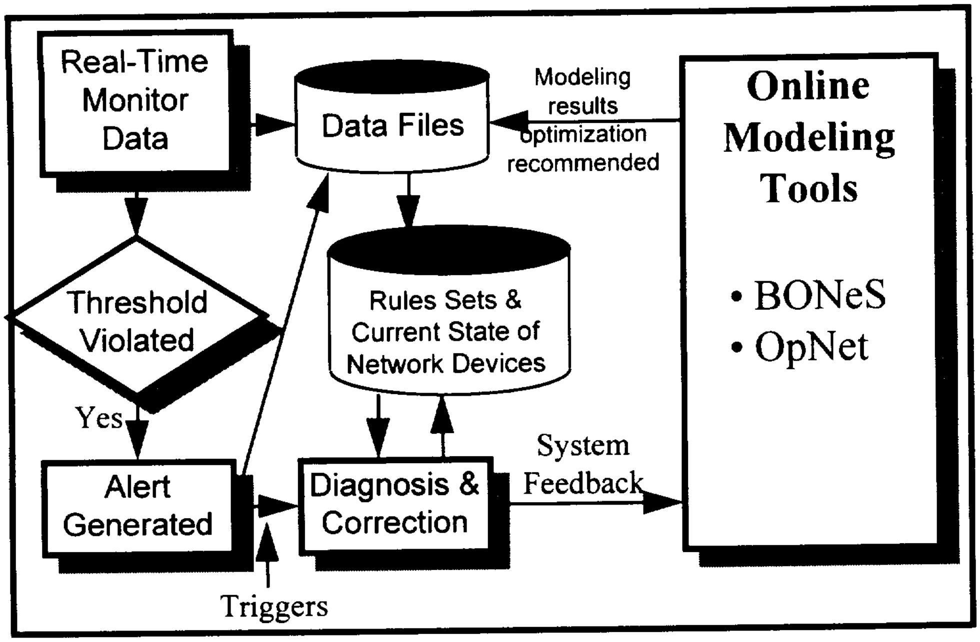

Figure 4-6. Network Management Process

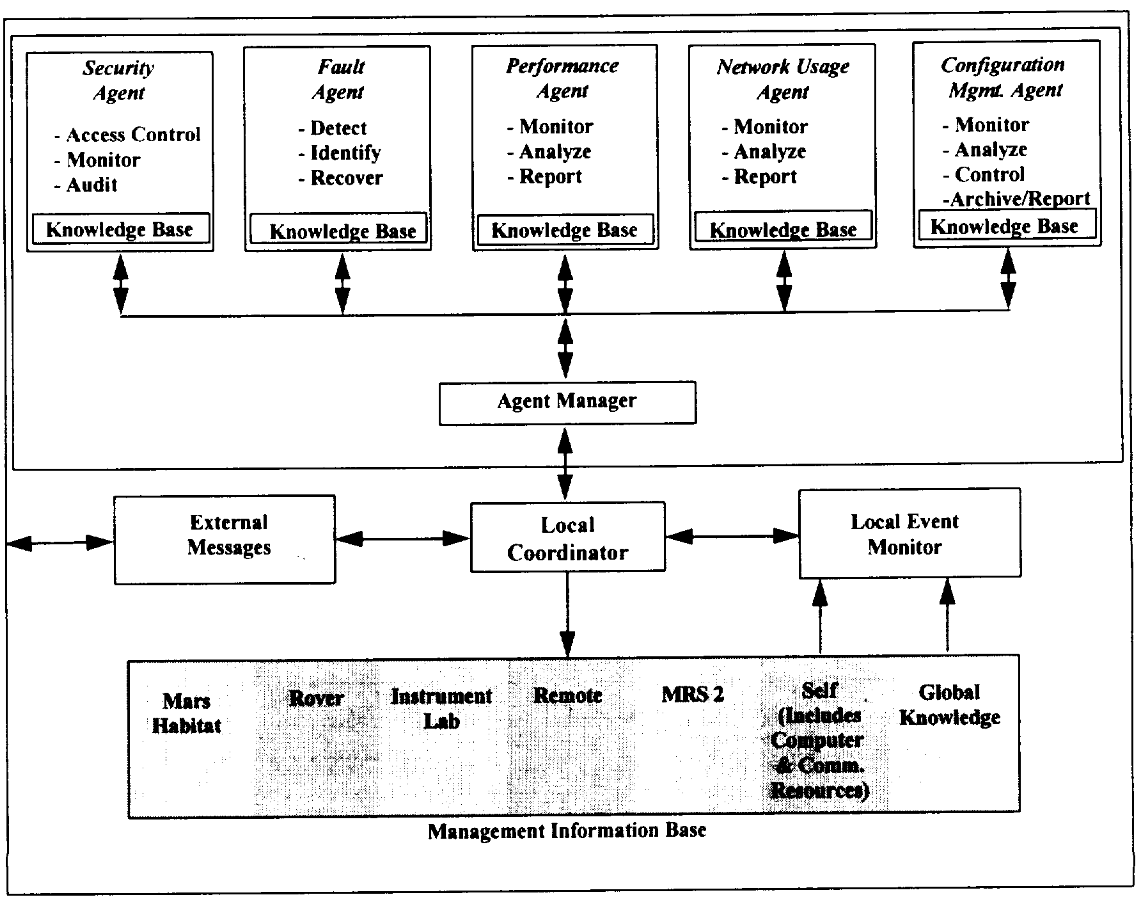

Figure 4-7. Multi-agent System Implementation Architecture for the Managing Mars Relay Satellite

One of the duties of the Local Coordinator is to act as the external interface to the rest of the network. Thus, the Local Coordinator accepts incoming messages and determines what should be done with them, as well as sending out its own node's messages. An important aspect of this task is that the Local Coordinator for each node is responsible for monitoring the status of its immediate neighbors on the network. The Local Coordinator for each node must poll its immediate neighbors, and if it doesn't receive an answer within the specified period of time, the Local Coordinator must notify both the primary MRS and the backup MRS2 of the suspected status of the node that failed to respond.

Another of the Local Coordinator's tasks is to update the Management Information Base (MIB). The structure of each node's MIB is different. The MIB for each node except MRS and MRS2 will only contain information about its own node (Self) plus any global information (Global Info) that has been disseminated. MRS and MRS2, however, will each receive and maintain a complete copy of the entire network's MIBs, as illustrated in Figure 4-8. Thus, whenever data is sent to MRS, a duplicate set must be sent to MRS2.

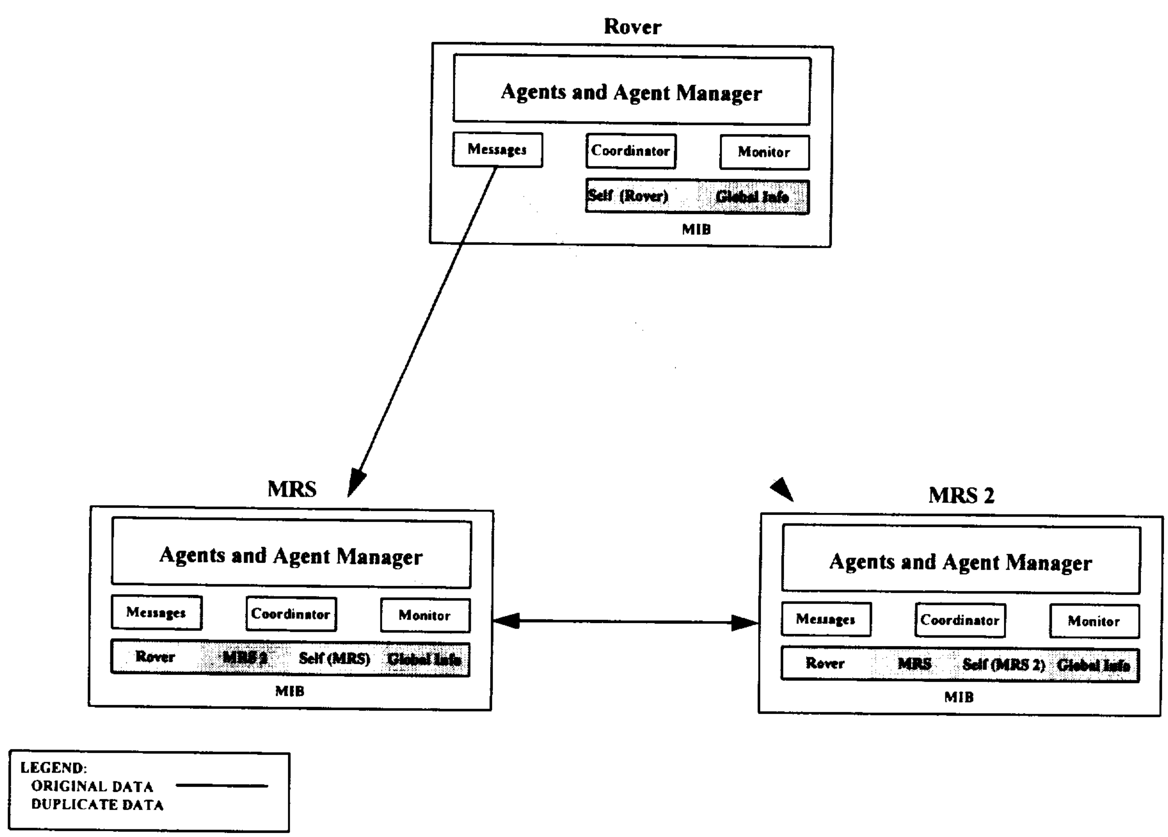

Figure 4-8. Interactions Between Network Elements in the Mars Region

Finally, the Local Coordinator's other task is to act as the interface to the Local Event Monitor, whose job is to monitor the database and sound an alarm if any exceptions occur (e.g., thresholds exceeded) on its local node. Since this is a Local Event Monitor, in the case of MRS and MRS 2, it will monitor only the "Global Knowledge" and "Self" partitions of the database unless it is instructed (by its Local Coordinator) to examine the other partitions of the database.

4.4 PROTOTYPE FOR UNATTENDED NETWORK OPERATION FOR THE PRIMARY MARS RELAY SATELLITE

A prototype for the architecture depicted in Figure 4-7 has been developed to support fault detection, isolation, and recovery. This program simulates a scenario where a node stops routing messages and it is necessary to isolate and recover from the fault. An alarm is triggered through a database write by an appropriate entity. The local event monitor detects the problem from a database read. This agent takes the alarm and analyzes the system for localization, possible causes, etc. as explained in Figure 4-5. Once the cause is identified, fault correction schemes are employed by the fault management agent. Recommendations, corrections, and suggestions are made and sent to the appropriate agent. If the routing table is deemed corrupt, it will be reconfigured. This scheme is sent to the configuration management agent where the routing table is reconfigured and the problem is resolved. A description of the steps for testing the scenario is presented in the next paragraph. A listing of the source code for the fault management specialist agent and the output generated from loading and executing the system is provided in Appendix C. The complete CLIPS source code for the multi-agent system including the event monitor, the coordinator, and the agent manager is too large to be included. They are provided on the tape holding the TIMS simulator software.

To run the simulation model, execute <start-tims>.

When the prompt returns, execute <clips>.

At the CLIPS prompt type (batch send-alarm).

When the CLIPS prompt returns type (init).

When the CLIPS prompt returns type (alarm).

To see logged output, change directory to LOGS.

Look at the log.node file; logged information will be present stating alarms detected, actions taken, etc. A sample output of the log file is provided in Appendix C.

SECTION 5
CONCLUDING REMARKS

The results of our research into TIMS network modeling and management have been presented in the preceding sections. We successfully ported the antenna visibility software from FORTRAN to C and developed code for estimating orbital positions of LMOs. Given the amount of effort required to model the TIMS system with the Block-Oriented Network Simulator (BONeS) software, we recommended that future modeling activities should be performed with another network simulation tool such as the OpNet. The version of BONeS available to us is over 3 years old with several missing upgrades. In spite of its limitations, we have an operational TIMS network simulation model that aids in investigating the impact of network node failures and message ACK/NACK capabilities.

In paragraph 4.1 we gave the reader an idea of what is involved in managing conventional communication networks. This was done to provide an appreciation for the amount of resources required to develop a meaningful prototype to explore the feasibility of unattended network operations for the Mars region. It will be necessary to generate a comprehensive list of scenarios to exercise all network management functions in a single node. Once this has been done, a replication of this node with changes in the values of the parameters is all that is required for other network nodes. Each node can then manage itself autonomously and report operational exceptions to the Integrated Network Manager, i.e., the primary Mars Relay Satellite.

APPENDIX A

TIMS ANTENNA VISIBILITY DETERMINATION SOFTWARE

APPENDIX A
TIMS ANTENNA VISIBILITY DETERMINATION SOFTWARE

Getting Started

To run this program, you must have the executable TIMS.EXE and the input files INPUT.DAT and ASAP.INP. Both of these must reside in the same directory. While in the directory that holds these two files, type "RUN TIMS".

Input

Information about the communication network to be used is contained in the input file INPUT.DAT. This is an ASCII file which can be edited as necessary by the user. The start time, duration and time step are input interactively by the user at run-time.

Communications Network Information

There are nine variables whose values are read in from the file INPUT.DAT. Before setting up these values, a numbered list should be made of each location accepting.sending information that is of concern to the user. This file must exist in the same directory as the executable.

Variables

Following is each variable name to be set up, how that variable is declared, the meaning of the variable, and any restrictions on the variable.

HARDWARE integer

This is simply the number of locations in the communications network which are to be evaluated by the program. Limit is 9.

COMBO integer array [9][9]

This is an array of flags to determine which pairs of locations in the network are to pass information between them. 1 means check this link. 0 means ignore the link.

HOME integer array [9]

The planet associated with each corresponding location in the network. Planets are numbered 1-9 from inner to outer.

SURFACE integer array [9]

This is an array of flags to indicate whether the site is fixed to the home planet surface (1) or is orbiting (0).

SITES double array [9][7]

Each row of 7 elements corresponds to a site. If the site is fixed to the planet surface, the first three entries are latitude, longitude and altitude. If the site is orbiting, the entries are semi-major axis, eccentricity, inclination, right ascension of the ascending node, argument of perigee, mean anomaly and epoch time. The time format is YYYYDDD.hhmmss.

SUNFLAG integer

This flag dictates whether Sun occultation is considered in establishing visibility. 1 means yes. 0 means no.

MOONFLAG integer

Corresponding flag for Moon occultation.

POF integer array [9]

Corresponding flags for the planets. Because of the way visibility is computed and because positions are computed relative to the Earth, it is not permissible to compute Earth occultation. Planets are numbered 1-9 from inner to outer

Input File Format

The file containing the above variables which is read as input must be named INPUT.DAT and must exist in the same directory as the executable. Rules for the format of the file are as follows:

1. The variable names may not change.
2. There must be a comma between the COMBO indices.
3. The COMBO indices run from 1 to 9, not 0 to 8.
4. The last value of COMBO indices must be 0,0.
5. Values for HOME, SURFACE and SITES must have the same order.
6. The third value of POF should be 0.
7. Variable names must be in capital letters.
8. POF must be the last variable listed.

Time

There are three values of time which must be input interactively. These are requested by the program at run-time. The first value is the start time of the span to be evaluated. It consists of a year, day of the year, hours of the day, minutes into the next hour, and seconds into the next minute. The format of this time should look as follows: yyyy/ddd/hh:mm:ss. The next value requested is the span of time to be processed. This should be in units of minutes and should be an integer number of no more than six digits. The last value needed in the time step to take while processing the requested time span. This should be in units of seconds and be an integer number of no more than five digits.

Output

There are four files generated each time the program executes. VISIBILITY.DAT contains information on visibility between specific locations in the network. ENV_FAC.DAT contains information on the path distance through the atmosphere for each link. ANT_OUT.DAT contains the antenna azimuth and elevation angles for each of the requested links involving ground sites. WARNINGS.DAT contains time spans over which there is no communication between the sites. All four files are output to the same directory in which the executable resides.

VISIBILITY.DAT

This file contains information on the ability of two locations in the network to communicate with each other. The first column is the time of interest. Each of the following columns corresponds to one of the combinations of locations listed under the variable "COMBO" in INPUT.DAT. A "YES" indicates that the two locations are able to pass information between them. A "NO" indicates that they cannot. The specific combinations each column represents is listed in the first row.

ENV_FAC.DAT

This file contains information on environmental factors associated with network connections. Its contents can be used for determining the best path, time delay and success probability of signals. The first column is again the time of interest. The second column is the distance between the Earth and Mars. The third column is the angle in degrees between the Sun and Mars as seen from the Earth center. Columns labeled "ATMOSx" are the distance in kilometers through which a signal has to travel through the Earth's atmosphere. A "-1.0" is listed if the link is down.

ANT_OUT.DAT

This file contains the ground antenna azimuth and elevation angles in degrees required to make the link. The first column is the time. Elevation is measured from the local horizon, and azimuth is measure from the east direction with north being +90 degrees. A "-1.0" again indicates that the link is down.

WARNINGS.DAT

This file has outputs if there is a period of time within which no links are up. The start and end time of the no-link period are printed and a reason for the lack of link is given. Possible causes are: home planet occultation, Sun occultation, Moon occultation and other planet occultation.

APPENDIX B

TIMS SIMULATION NETWORKING MODELING - RESULTS

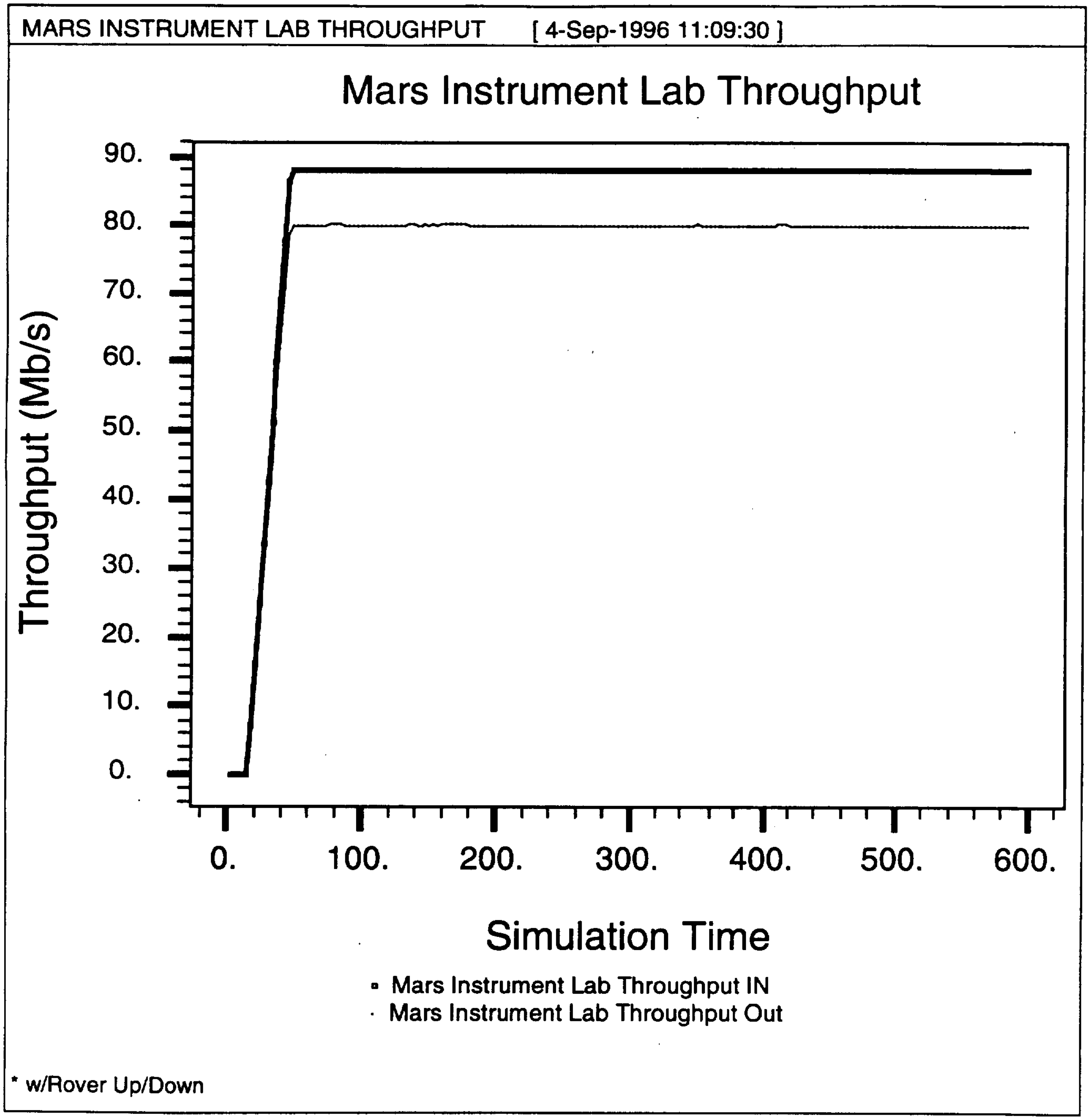

Figure B-1. Mars Instrument Lab Throughput

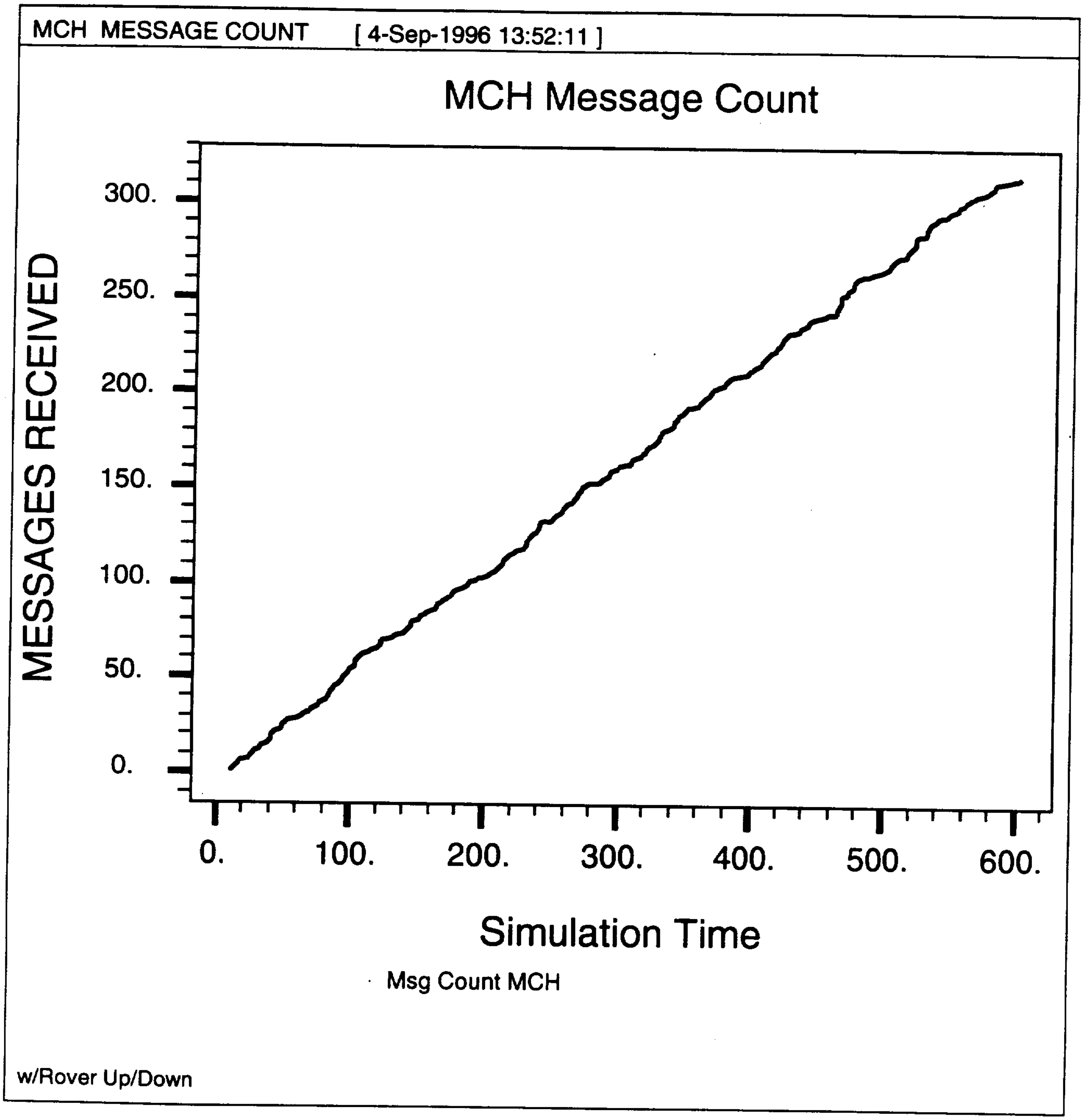

Figure B-2. MCH Message Count

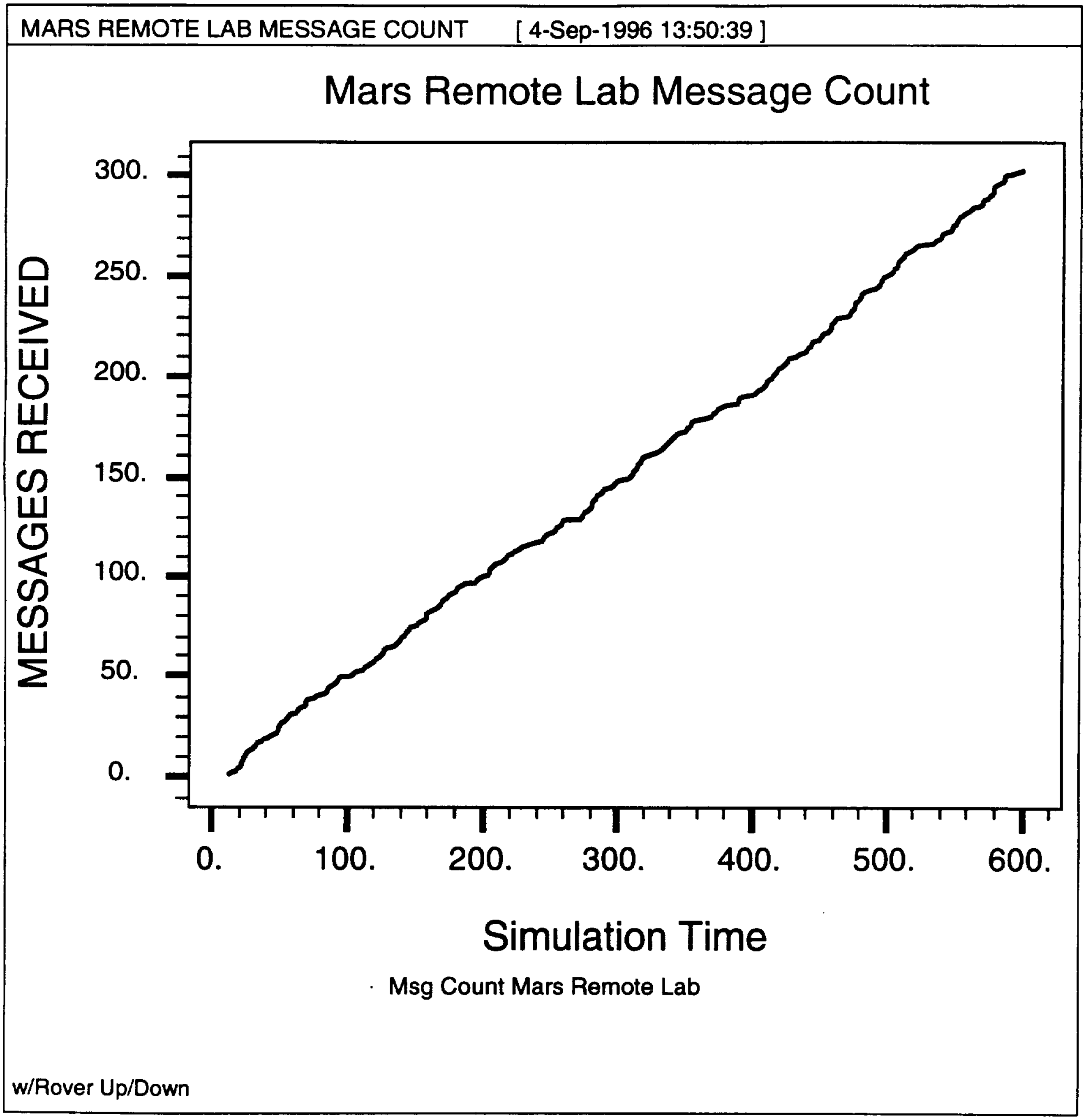

Figure B-3. Mars Remote Lab Message Count

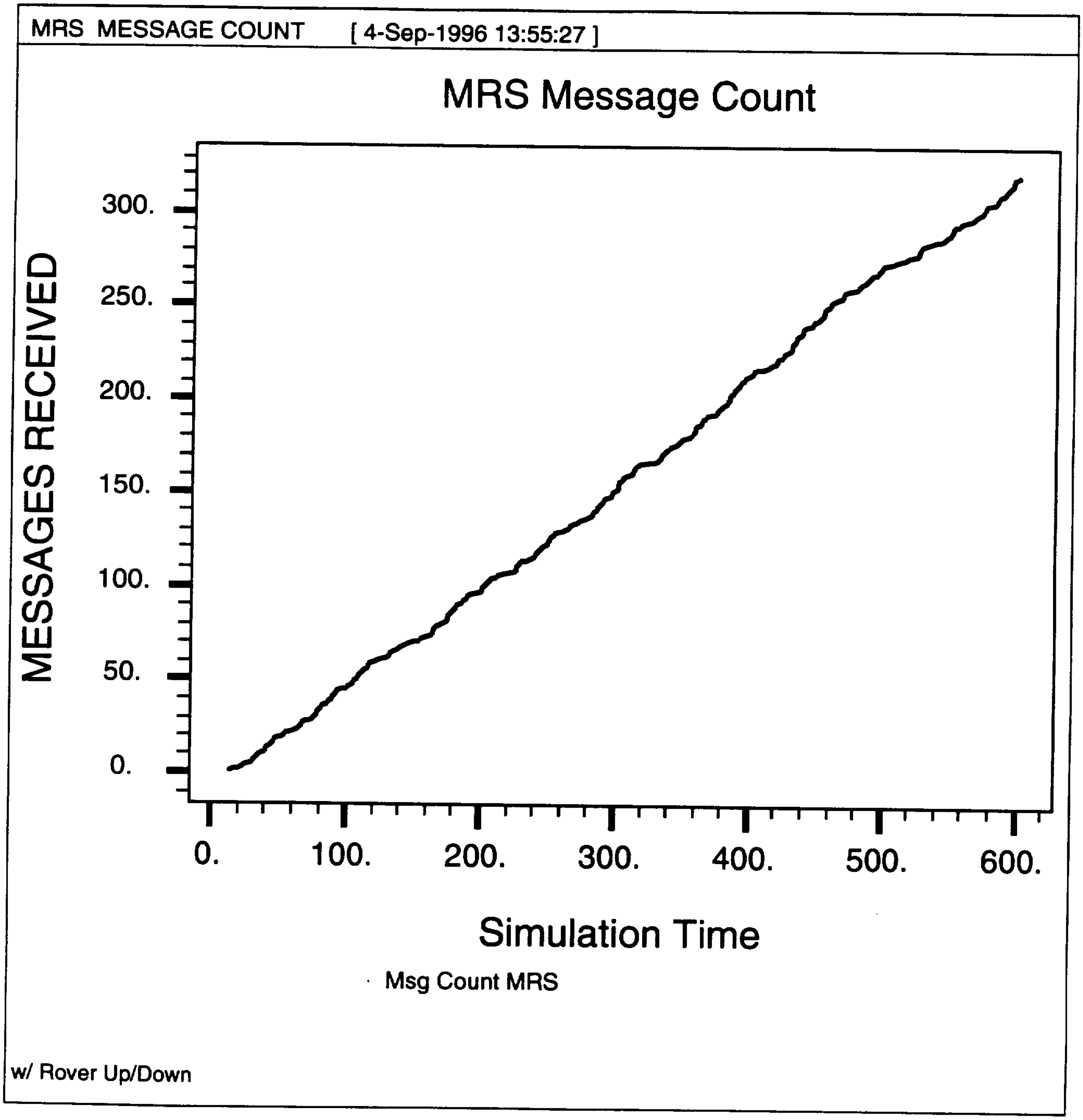

Figure B-4. MRS Message Count

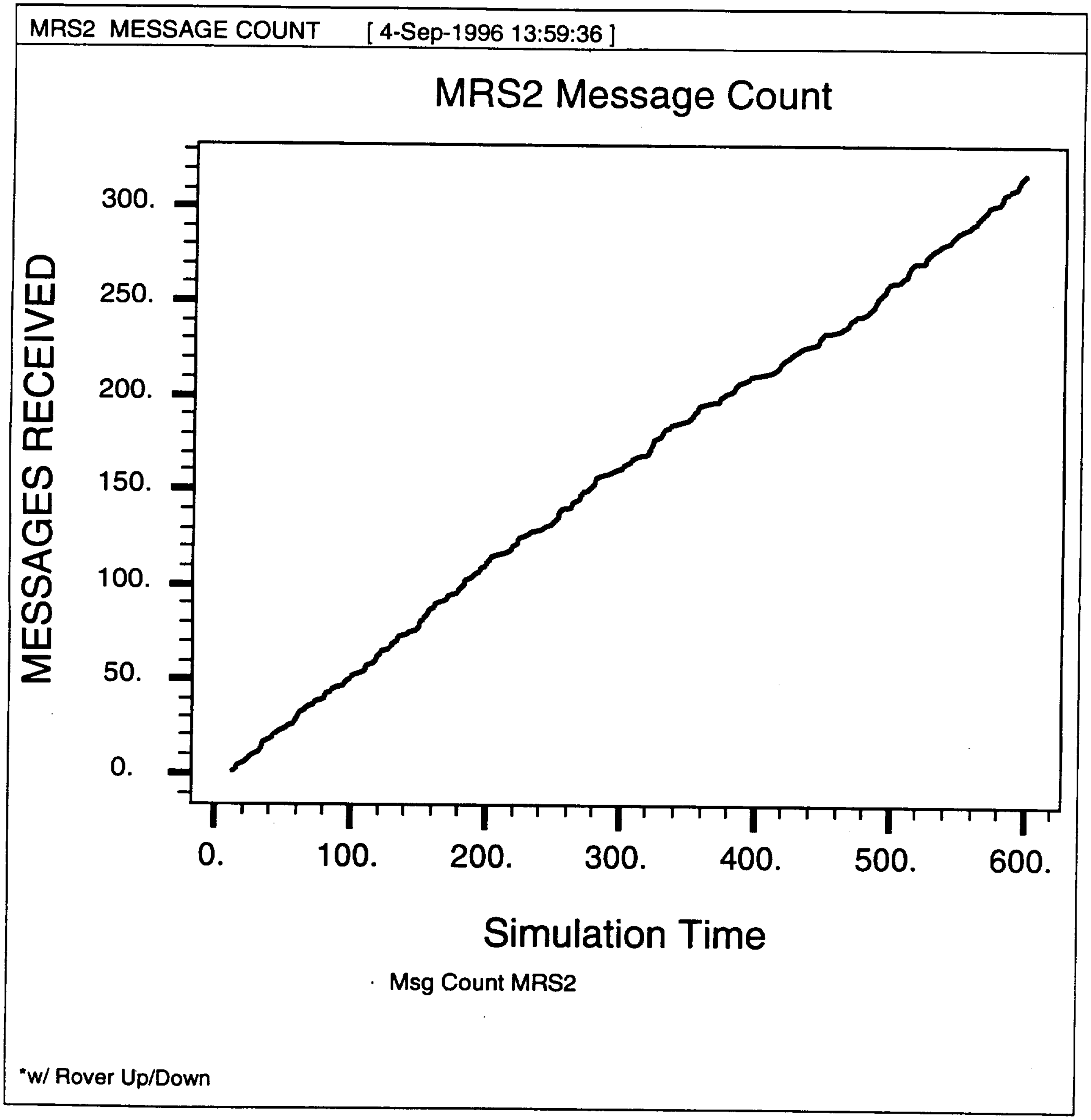

Figure B-5. MRS2 Message Count

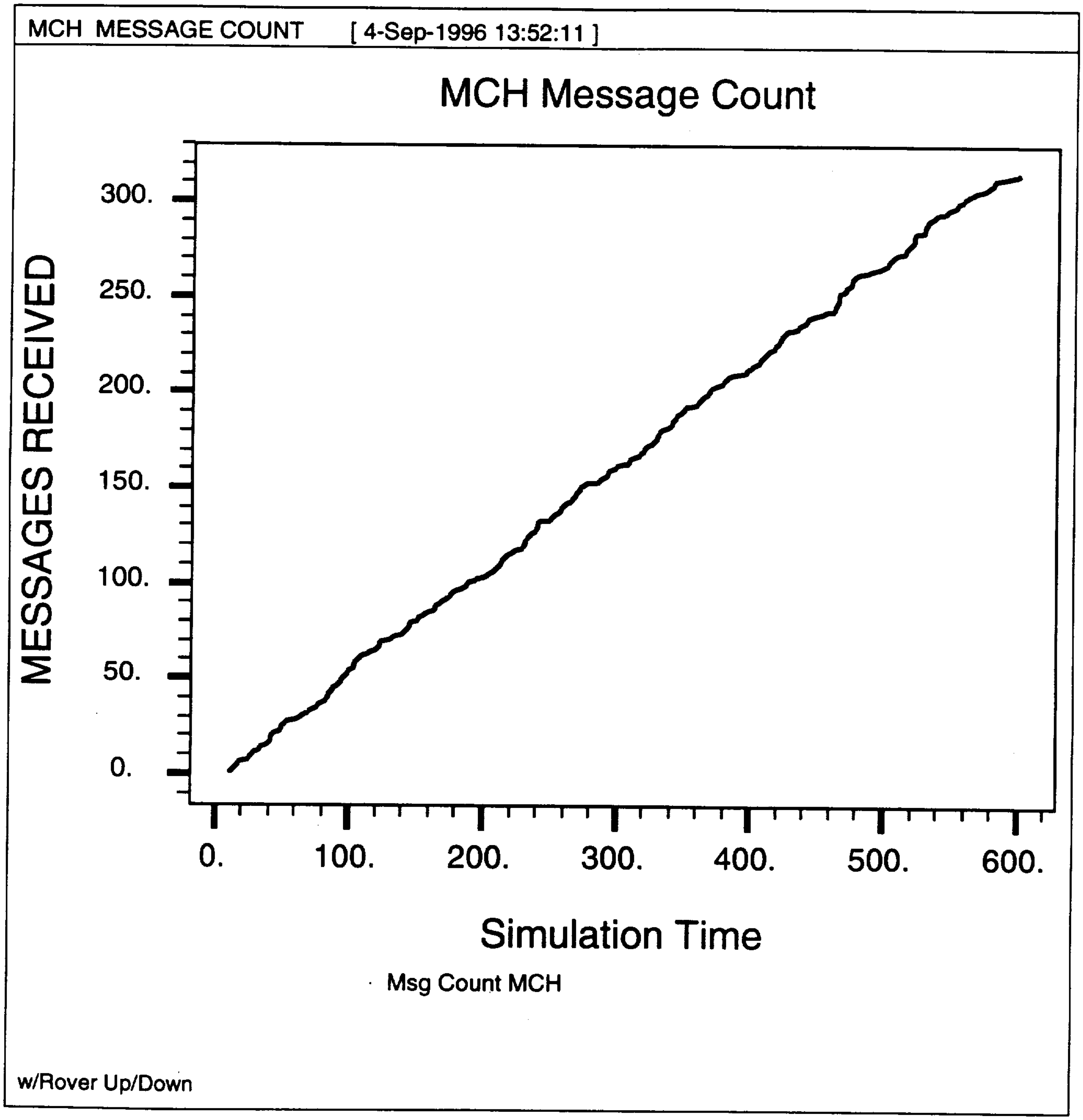

Figure B-6. MCH Message Count

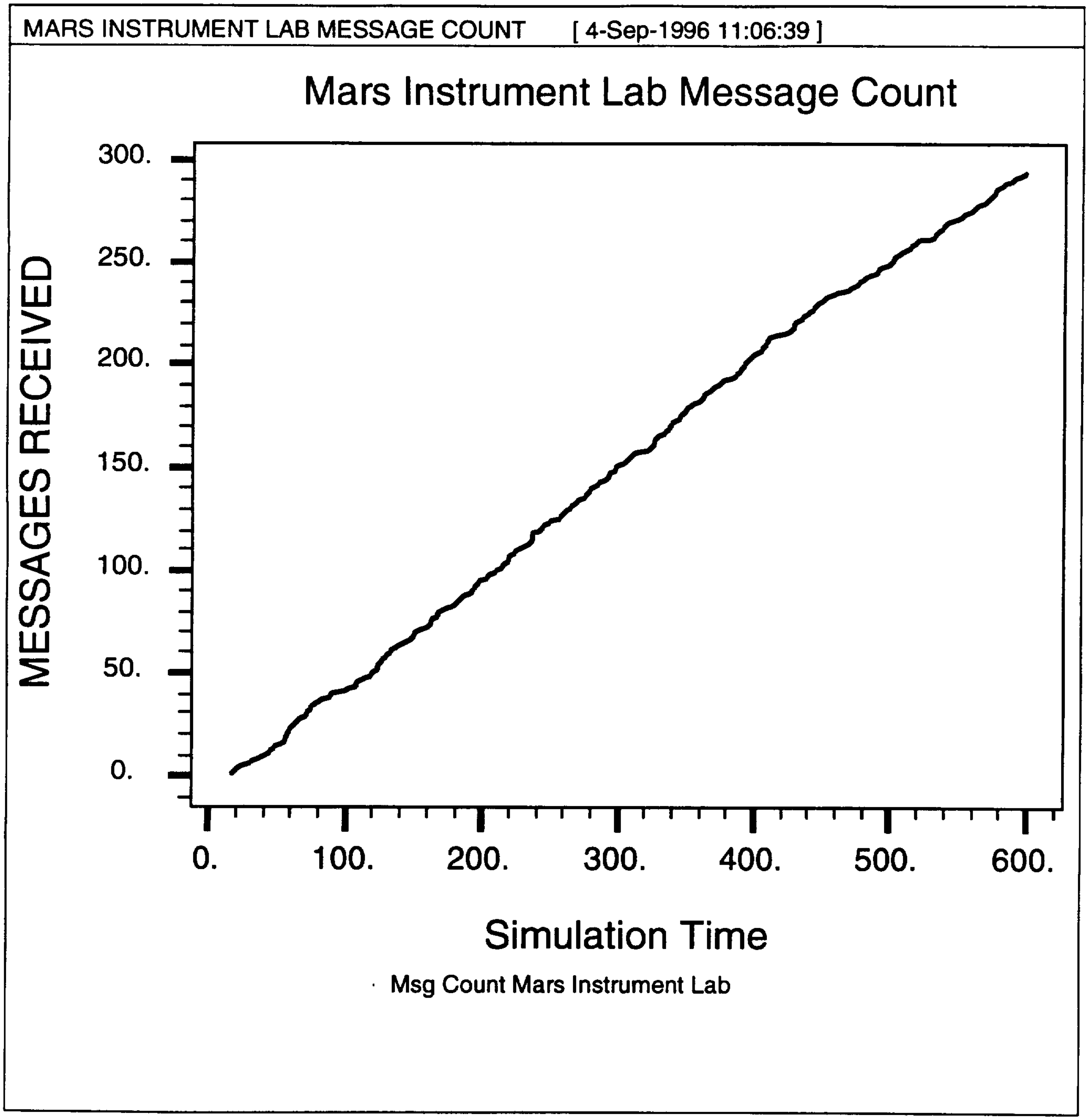

Figure B-7. Mars Instrument Lab Message Count

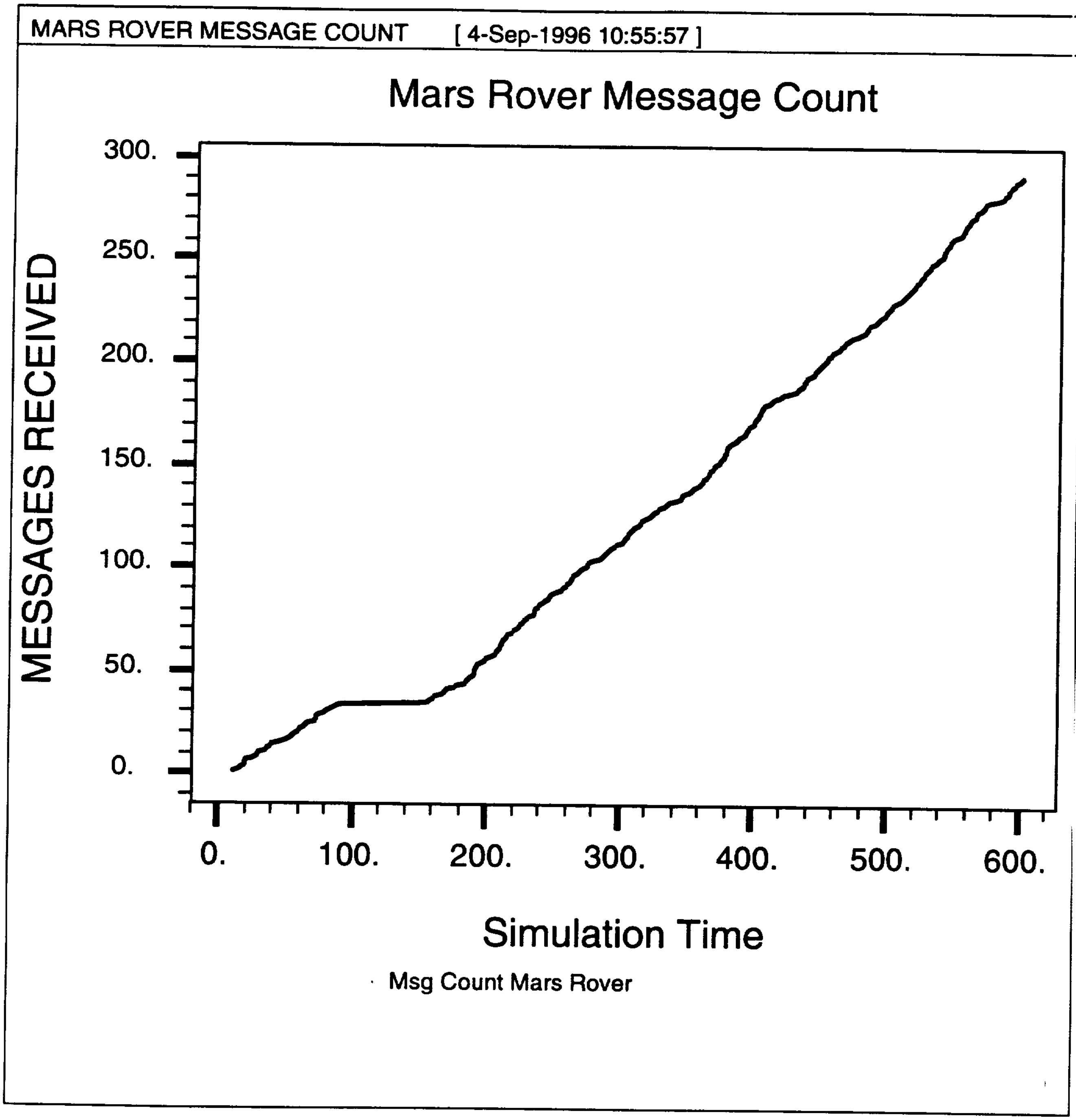

Figure B-8. Mars Rover Message Count

Sim2(Rover up/down) [Thursday, 9/5/96 09:48:49 am EST]

Simulation Parameters:

Parameter Name: Visibility Table String
Type: STRING

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4 5 0 4 5 0 4 5 0
"
```

Parameter Name: Deep Space Link Capacity
Type: REAL ; Subrange: [0, +Infinity)
Expression: 5.0E7

Parameter Name: Routing Table String
Type: STRING
Expression:

```
 0 13  3  4  5  6  5  5  5  5  5  5 13 14  3
13  0 15  4  5  6  5  5  5  5  5  5 13 14 15
 1 15  0  4  5  6  5  5  5  5  5  5  1 14 15
 1  2  3  0  7  7  7  7  7  7  7  7  1  1  1
 1  2  3  7  0  7  7  7  7  7  7  7  1  1  1
 1  2  3  7  7  0  7  7  7  7  7  7  1  1  1
 5  5  5  4  5  6  0  8  8  8  8  8  5  5  5
 7  7  7  7  7  7  7  0  9  9  9  9  7  7  7
 8  8  8  8  8  8  8  8  0 10 11 12  8  8  8
 9  9  9  9  9  9  9  9  9  0 11  9  9  9  9
 9  9  9  9  9  9  9  9  9 10  0  9  9  9  9
 9  9  9  9  9  9  9  9  9  9  9  0  9  9  9
 1  2  1  1  1  1  1  1  1  1  1  1  0  2  2
 1  2  3  1  1  1  1  1  1  1  1  1  2  0 15
 3  2  3  2  2  2  2  2  2  2  2  2  2 14  0
```

Value: "

```
 0 13  3  4  5  6  5  5  5  5  5  5 13 14  3
13  0 15  4  5  6  5  5  5  5  5  5 13 14 15
 1 15  0  4  5  6  5  5  5  5  5  5  1 14 15
 1  2  3  0  7  7  7  7  7  7  7  7  1  1  1
 1  2  3  7  0  7  7  7  7  7  7  7  1  1  1
 1  2  3  7  7  0  7  7  7  7  7  7  1  1  1
 5  5  5  4  5  6  0  8  8  8  8  8  5  5  5
 7  7  7  7  7  7  7  0  9  9  9  9  7  7  7
 8  8  8  8  8  8  8  8  0 10 11 12  8  8  8
 9  9  9  9  9  9  9  9  9  0 11  9  9  9  9
 9  9  9  9  9  9  9  9  9 10  0  9  9  9  9
 9  9  9  9  9  9  9  9  9  9  9  0  9  9  9
```

1 2 1 1 1 1 1 1 1 1 1 1 1 0 2 2
1 2 3 1 1 1 1 1 1 1 1 1 1 2 0 15
3 2 3 2 2 2 2 2 2 2 2 2 2 2 14 0

"

Parameter Name: Number of Nodes
Type: INTEGER ; Subrange: [0, +Infinity)
Expression: 15.0
Value: 15

Parameter Name: Valid Mars Destination String
Type: STRING
Expression: 1 2 3 13 14 15
Value: "1 2 3 13 14 15"

Parameter Name: Valid Earth Destination String
Type: STRING
Expression: 10 11 12
Value: "10 11 12"

Parameter Name: Global Delay Window Size
Type: REAL ; Subrange: (-Infinity, +Infinity)
Expression: 'Sample Period (Average Delay)' * 10.0
Value: 300.0

Parameter Name: Sample Period (Average Delay)
Type: REAL ; Subrange: (-Infinity, +Infinity)
Expression: 'TSTOP' / 20.0
Value: 30.0

Parameter Name: Alt Routing Table String
Type: STRING
Expression: 0 13 14 4 5 6 5 5 5 5 5 5 13 14 14
13 0 15 4 5 6 5 5 5 5 5 5 13 14 15
14 15 0 4 5 6 5 5 5 5 5 5 6 14 15
99 99 99 0 7 7 7 7 7 7 7 7 2 2 2
99 99 99 7 0 7 7 7 7 7 7 7 2 2 2
99 99 99 7 7 0 7 7 7 7 7 7 2 2 2
5 5 5 4 5 6 0 8 9 10 11 12 5 5 5
7 7 7 7 7 7 7 0 9 9 9 9 7 7 7
8 8 8 8 8 8 8 8 0 10 11 12 8 8 8
9 9 9 9 9 9 9 9 0 11 9 9 9 9
9 9 9 9 9 9 9 9 9 0 9 9 9 9
9 9 9 9 9 9 9 9 9 9 0 9 9 9
2 2 2 2 2 2 2 2 2 2 2 2 2 2
2 2 2 2 2 2 2 2 2 2 2 2 0 15
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Value: "0 13 14 4 5 6 5 5 5 5 5 5 13 14 14
13 0 15 4 5 6 5 5 5 5 5 5 13 14 15
14 15 0 4 5 6 5 5 5 5 5 5 6 14 15
99 99 99 0 7 7 7 7 7 7 7 7 2 2 2
99 99 99 7 0 7 7 7 7 7 7 7 2 2 2
99 99 99 7 7 0 7 7 7 7 7 7 2 2 2
5 5 5 4 5 6 0 8 9 10 11 12 5 5 5
7 7 7 7 7 7 7 0 9 9 9 9 7 7 7
8 8 8 8 8 8 8 8 0 10 11 12 8 8 8
9 9 9 9 9 9 9 9 0 11 9 9 9 9
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2 2 2 2 2 2 2 2 2 2 2 2 2 2
2 2 2 2 2 2 2 2 2 2 2 2 0 15

2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 0

Parameter Name: TSTOP
Type: REAL ; Subrange: (0.0, +Infinity)
Expression: 600.0

Parameter Name: Global Seed
Type: INTEGER ; Subrange: (0, +Infinity]
Expression: 322456.0
Value: 322456

===

Simulation Probes:

Probe Name: Remote Lab Post Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Remote Lab-> Merge-> Output
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Remote Lab Pre-Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Remote Lab-> Communication Processor(v.2)-> Packet In
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Mars Rover Post Processing Throughput
Probing Module: Throughput vs Time Probe

Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Rover-> Merge-> Output
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Mars Rover Pre-Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Rover-> Communication Processor(v.2)-> Packet In
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Mars Instrument Lab Post Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Instrument Lab-> Merge-> Output
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Mars Instrument Lab Pre-Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Instrument Lab-> Communication Processor(v.2)-> Packet In
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: MCH Antenna Post Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> MCH-> Merge-> Output
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: MCH Antenna Pre-Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> MCH-> Comm. Proc. Mars SAT(v.2)-> Packet In
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period

Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: MRS2 Antenna Post Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> MRS2-> Merge-> Output
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: MRS2 Antenna Pre-Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> MRS2-> Comm. Proc. Mars SAT(v.2)-> Packet In
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: MRS Antenna Post Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> MRS-> Merge-> Output
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: MRS Antenna Pre-Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> MRS-> Comm. Proc. Mars SAT(v.2)-> Packet In
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Canberra Antenna Post Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Canberra Ground Antenna-> Merge-> Output
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Canberra Antenna Pre-Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Canberra Ground Antenna-> Comm. Proc-Ground Antenna(v.2)-> Packet In
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Goldstone Antenna Post Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Goldstone Ground Antenna-> Merge-> Output
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Goldstone Antenna Pre-Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Goldstone Ground Antenna-> Comm. Proc-Ground Antenna(v.2)-> Packet In
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Madrid Antenna Post Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Madrid Ground Antenna-> Merge-> Output
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Madrid Antenna Pre-Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Madrid Ground Antenna-> Comm. Proc-Ground Antenna(v.2)-> Packet In
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: NIF Post Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> NIF/Central Comm. Center-> Merge-> Output
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: NIF Pre-Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> NIF/Central Comm. Center-> Comm. Proc. Earth /Deep Space(v.2)-> Packet In
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: NASCOM Switching Center Post Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> NASCOM-> Merge-> Output
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: NASCOM Switching Center Pre-Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> NASCOM-> Communication Processor(v.2)-> Packet In
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Earth Communication Hub Post Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Earth Comm. Hub-> Merge-> Output

Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Earth Communication Hub Pre-Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Earth Comm. Hub-> Communication Processor(v.2)-> Packet In
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Mars Ops Cntrl Cntr Post Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Mars Ops. Control Center-> Merge-> Output
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Mars Ops Cntrl Cntr Pre-Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Mars Ops. Control Center-> Communication Processor(v.2)-> Packet In
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Science Data Proc Fac Post Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Science Data Proc. Facility-> Merge-> Output
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Science Data Proc Fac Pre-Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Science Data Proc. Facility-> Communication Processor(v.2)-> Packet In
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period

Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Net Mngmt Cntr Post Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Mars Comm. Net Mangmt Center-> Merge-> Output
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Net Mngmt Cntr Pre-Processing Throughput
Probing Module: Throughput vs Time Probe
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Mars Comm. Net Mangmt Center-> Communication Processor(v.2)-> Packet In
Type Filter: Network Message
Fields: Throughput ; TNOW

Probe Parameters:
Parameter Name: Selected Field
Expression: Length

Parameter Name: Capacity
Expression: 1.0

Parameter Name: Time Between Output Samples
Expression: 'TSTOP' / 200.0
Value: 3.0

Parameter Name: Window Period
Expression: 'Time Between Output Samples' * 10.0
Value: 30.0

Probe Name: Mesg Count MRS
Probing Module: *Generic Probe*
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Message Counter MRS
Type Filter: INTEGER
Fields: count ; TNOW

Probe Parameters:
Parameter Name: Probe Start
Expression: 0.0

Parameter Name: Probe Stop
Expression: 'TSTOP'
Value: 600.0

Probe Name: Mesg Count MRS2
Probing Module: *Generic Probe*
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Message Counter MRS2
Type Filter: INTEGER
Fields: count ; TNOW

Probe Parameters:
Parameter Name: Probe Start
Expression: 0.0

Parameter Name: Probe Stop
Expression: 'TSTOP'
Value: 600.0

Probe Name: Mesg Count MCH
Probing Module: *Generic Probe*
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Message Counter MCH
Type Filter: INTEGER
Fields: count ; TNOW

Probe Parameters:
Parameter Name: Probe Start
Expression: 0.0

Parameter Name: Probe Stop
Expression: 'TSTOP'
Value: 600.0

Probe Name: Mesg Count Mars Remote Lab
Probing Module: *Generic Probe*
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Message Counter Mars Rem. Lab
Type Filter: INTEGER
Fields: count ; TNOW

Probe Parameters:
Parameter Name: Probe Start
Expression: 0.0

Parameter Name: Probe Stop
Expression: 'TSTOP'
Value: 600.0

Probe Name: Mesg Count Mars Rover
Probing Module: *Generic Probe*
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Message Counter Mars Rover
Type Filter: INTEGER
Fields: count ; TNOW

Probe Parameters:
Parameter Name: Probe Start
Expression: 0.0

Parameter Name: Probe Stop
Expression: 'TSTOP'
Value: 600.0

Probe Name: Mesg Count Mars Instr. Lab
Probing Module: *Generic Probe*
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Message Count Mars Instr. Lab

Type Filter: INTEGER
Fields: count ; TNOW

Probe Parameters:
Parameter Name: Probe Start
Expression: 0.0

Parameter Name: Probe Stop
Expression: 'TSTOP'
Value: 600.0

Probe Name: Mesg Count Mars Ops Cntrl Center
Probing Module: *Generic Probe*
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Mesg Count Mars Ops Cntrl Cntr
Type Filter: INTEGER
Fields: count ; TNOW

Probe Parameters:
Parameter Name: Probe Start
Expression: 0.0

Parameter Name: Probe Stop
Expression: 'TSTOP'
Value: 600.0

Probe Name: Mesg Count Science Data Fac
Probing Module: *Generic Probe*
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Mesg Count Science Proc Fac
Type Filter: INTEGER
Fields: count ; TNOW

Probe Parameters:
Parameter Name: Probe Start
Expression: 0.0

Parameter Name: Probe Stop
Expression: 'TSTOP'
Value: 600.0

Probe Name: Msg Count Mars Net Mngmt Cntr
Probing Module: *Generic Probe*
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Mesg Count Net Mngmt Center
Type Filter: INTEGER
Fields: count ; TNOW

Probe Parameters:
Parameter Name: Probe Start
Expression: 0.0

Parameter Name: Probe Stop
Expression: 'TSTOP'
Value: 600.0

Probe Name: Network Average Delay
Probing Module: *Generic Probe*
Location: Earth-Mars Communication Network(v.2)-Rover UP/DOWN-> Network INIT(v.2)-> Compute Global Average Delay(v.2)-> R/-> Output
Type Filter: REAL
Fields: Average Delay ; TNOW

Probe Parameters:
Parameter Name: Probe Start
Expression: 0.0

Parameter Name: Probe Stop
Expression: 'TSTOP'
Value: 600.0

APPENDIX C

NETWORK MANAGEMENT PROTOTYPE

Output from loading and executing the fault management specialist agent

```
   SAIRE 2.0 Non-Graphic
         SSI 1.0 clp6.03
     CLIPS (V6.03 06/15/95)
CLIPS> ;;;==================================
;;;batch file
;;;==================================

(clear)
CLIPS> (close)
FALSE
CLIPS> (reset)
CLIPS>
(watch facts)
CLIPS> (watch focus)
CLIPS> (watch rules)
CLIPS>
(load specialist-class.clp)
Redefining defmodule: MAIN
Defining defclass: SPECIALIST
TRUE
CLIPS> (load message-class.clp)
Defining defclass: MSG-CLASS
TRUE
CLIPS> (load manager-class.clp)
Defining defclass: shared-memory
Defining defclass: msg-frame
Defining defclass: MANAGER
Defining defglobal: running
Defining defglobal: screen-width
Defining defglobal: screen-height
Defining defglobal: sun-os
Defining defglobal: linux-os
Defining defglobal: KNOWN-PORT
Defining defmessage-handler: MANAGER
  Handler check-local-msgs primary defined.
Defining defmessage-handler: MANAGER
  Handler agent-group-msgs primary defined.
Defining defmessage-handler: MANAGER
  Handler Manager-loop primary defined.
Defining defmessage-handler: MANAGER
  Handler do-Incoming-Msgs primary defined.
Defining defmessage-handler: MANAGER
  Handler Response-Daemon primary defined.
Defining defmessage-handler: MANAGER
  Handler Service-Daemon primary defined.
Defining defmessage-handler: MANAGER
  Handler do-Outgoing-Msgs primary defined.
Defining defmessage-handler: MANAGER
  Handler check-load primary defined.
Defining defmessage-handler: MANAGER
  Handler check-my-workload primary defined.
```

```
Defining defmessage-handler: MANAGER
  Handler tag-agent primary defined.
Defining defmessage-handler: MANAGER
  Handler tag-msg primary defined.
Defining defmessage-handler: MANAGER
  Handler get-unix-vendor primary defined.
Defining defglobal: port
Defining defmessage-handler: MANAGER
  Handler send-non-local-msg primary defined.
Defining defmessage-handler: MANAGER
  Handler get-non-local-msg1 primary defined.
Defining defmessage-handler: MANAGER
  Handler get-non-local-msg primary defined.
Defining defmessage-handler: MANAGER
  Handler shutdown primary defined.
Defining defmessage-handler: MANAGER
  Handler convert-msg-frame-to-string primary defined.
Defining defmessage-handler: MANAGER
  Handler convert-string-to-msg-frame primary defined.
Defining defmessage-handler: MANAGER
  Handler tag-frame primary defined.
Defining defmessage-handler: MANAGER
  Handler connect-with-coordinator primary defined.
TRUE
CLIPS>
(make-instance [MAIN::shared-memory] of shared-memory)
[shared-memory]
CLIPS>
(load security-specialist.clp)
Defining defmodule: SECURITY-Agent
Defining defclass: msg-frame
Defining defclass: security-specialist
Defining defglobal: frame
Defining defglobal: frame-list
Defining defglobal: new-frame-list
Defining defmessage-handler: security-specialist
  Handler Outgoing-msg-Daemon primary defined.
Defining defmessage-handler: security-specialist
  Handler Strategy-goal-Daemon primary defined.
Defining defmessage-handler: security-specialist
  Handler Strategy-goal-Daemon after defined.
Defining deffunction: get-local-msgs
Defining defrule: activation-rule +j
Defining defrule: p-schema_Route +j+j+j
Defining defmessage-handler: security-specialist
  Handler convert-msg-frame-to-string primary defined.
Defining defmessage-handler: security-specialist
  Handler convert-string-to-msg-frame primary defined.
Defining defmessage-handler: security-specialist
  Handler tag-frame primary defined.
Defining defmessage-handler: security-specialist
  Handler tag-msg primary defined.
TRUE
CLIPS> (focus SECURITY-Agent)
```

```
==> Focus SECURITY-Agent from MAIN
TRUE
CLIPS> (make-instance [security-agent] of security-specialist)
[security-agent]
CLIPS>
(load fault-specialist.clp)
Defining defmodule: FAULT-Agent
Defining defclass: msg-frame
Defining defclass: fault-specialist
Defining defglobal: frame
Defining defglobal: frame-list
Defining defglobal: new-frame-list
Defining defmessage-handler: fault-specialist
  Handler Outgoing-msg-Daemon primary defined.
Defining defmessage-handler: fault-specialist
  Handler Strategy-goal-Daemon primary defined.
Defining defmessage-handler: fault-specialist
  Handler Strategy-goal-Daemon after defined.
Defining deffunction: get-local-msgs
Defining deffunction: check-links
Defining deffunction: check-sys
Defining deffunction: check-tables
Defining deffunction: fault-diagnosis
Defining defrule: activation-rule +j
Defining defrule: p-schema_Alarm-routing +j
Defining defrule: p-schema_Fault_Correction_Routing +j+j+j
Defining defrule: p-schema_Route +j+j+j
Defining defmessage-handler: fault-specialist
  Handler convert-msg-frame-to-string primary defined.
Defining defmessage-handler: fault-specialist
  Handler convert-string-to-msg-frame primary defined.
Defining defmessage-handler: fault-specialist
  Handler tag-frame primary defined.
Defining defmessage-handler: fault-specialist
  Handler tag-msg primary defined.
TRUE
CLIPS> (focus FAULT-Agent)
==> Focus FAULT-Agent from SECURITY-Agent
TRUE
CLIPS> (make-instance [fault-agent] of fault-specialist)
[fault-agent]
CLIPS>
(load performance-specialist.clp)
Defining defmodule: PERFORMANCE-Agent
Defining defclass: msg-frame
Defining defclass: performance-specialist
Defining defglobal: frame
Defining defglobal: frame-list
Defining defglobal: new-frame-list
Defining defmessage-handler: performance-specialist
  Handler Outgoing-msg-Daemon primary defined.
Defining defmessage-handler: performance-specialist
  Handler Strategy-goal-Daemon primary defined.
Defining defmessage-handler: performance-specialist
```

```
  Handler Strategy-goal-Daemon after defined.
Defining deffunction: get-local-msgs
Defining defrule: activation-rule +j
Defining defrule: p-schema_Route +j+j+j
Defining defmessage-handler: performance-specialist
  Handler convert-msg-frame-to-string primary defined.
Defining defmessage-handler: performance-specialist
  Handler convert-string-to-msg-frame primary defined.
Defining defmessage-handler: performance-specialist
  Handler tag-frame primary defined.
Defining defmessage-handler: performance-specialist
  Handler tag-msg primary defined.
TRUE
CLIPS> (focus PERFORMANCE-Agent)
==> Focus PERFORMANCE-Agent from FAULT-Agent
TRUE
CLIPS> (make-instance [performance-agent] of performance-specialist)
[performance-agent]
CLIPS>
(load net-usage-specialist.clp)
Defining defmodule: NET-USAGE-Agent
Defining defclass: msg-frame
Defining defclass: net-usage-specialist
Defining defglobal: frame
Defining defglobal: frame-list
Defining defglobal: new-frame-list
Defining defmessage-handler: net-usage-specialist
  Handler Outgoing-msg-Daemon primary defined.
Defining defmessage-handler: net-usage-specialist
  Handler Strategy-goal-Daemon primary defined.
Defining defmessage-handler: net-usage-specialist
  Handler Strategy-goal-Daemon after defined.
Defining deffunction: get-local-msgs
Defining defrule: activation-rule +j
Defining defrule: p-schema_Route +j+j+j
Defining defmessage-handler: net-usage-specialist
  Handler convert-msg-frame-to-string primary defined.
Defining defmessage-handler: net-usage-specialist
  Handler convert-string-to-msg-frame primary defined.
Defining defmessage-handler: net-usage-specialist
  Handler tag-frame primary defined.
Defining defmessage-handler: net-usage-specialist
  Handler tag-msg primary defined.
TRUE
CLIPS> (focus NET-USAGE-Agent)
==> Focus NET-USAGE-Agent from PERFORMANCE-Agent
TRUE
CLIPS> (make-instance [NET-USAGE-agent] of net-usage-specialist)
[NET-USAGE-agent]
CLIPS>

(load conf-mngmt-specialist.clp)
Defining defmodule: CONF-MNGMT-Agent
Defining defclass: msg-frame
```

```
Defining defclass: conf-mngmt-specialist
Defining defglobal: frame
Defining defglobal: frame-list
Defining defglobal: new-frame-list
Defining defmessage-handler: conf-mngmt-specialist
  Handler Outgoing-msg-Daemon primary defined.
Defining defmessage-handler: conf-mngmt-specialist
  Handler Strategy-goal-Daemon primary defined.
Defining defmessage-handler: conf-mngmt-specialist
  Handler Strategy-goal-Daemon after defined.
Defining deffunction: get-local-msgs
Defining defrule: activation-rule +j
Defining defrule: p-schema_reconfigure_tables +j
Defining defrule: p-schema_Route +j+j+j
Defining defmessage-handler: conf-mngmt-specialist
  Handler convert-msg-frame-to-string primary defined.
Defining defmessage-handler: conf-mngmt-specialist
  Handler convert-string-to-msg-frame primary defined.
Defining defmessage-handler: conf-mngmt-specialist
  Handler tag-frame primary defined.
Defining defmessage-handler: conf-mngmt-specialist
  Handler tag-msg primary defined.
TRUE
CLIPS> (focus CONF-MNGMT-Agent)
==> Focus CONF-MNGMT-Agent from NET-USAGE-Agent
TRUE
CLIPS> (make-instance [conf-mngmt-agent] of conf-mngmt-specialist)
[conf-mngmt-agent]
CLIPS>

(load node-manager.clp)
Defining defmodule: Agent-Manager
Defining defclass: node-manager
Defining defmessage-handler: node-manager
  Handler Initialize primary defined.
Defining defmessage-handler: node-manager
  Handler read-local-msgs primary defined.
Defining defrule: local-msgs +j
Defining defrule: agent-msgs +j
TRUE
CLIPS> (focus Agent-Manager)
==> Focus Agent-Manager from CONF-MNGMT-Agent
TRUE
CLIPS> (make-instance [node-manager] of node-manager)
[node-manager]
CLIPS> (send [node-manager] Initialize node-manager)
7
CLIPS>
;;starts running
(send [node-manager] Manager-loop)

sending...[MAIN::MSG-gen1] to fault-agent
avail-write: 1
==> Focus MAIN from Agent-Manager
```

```
[shared-memory] of shared-memory
(shared-msg-buffer "fault-agent" (Msg-ID alarm1) (Sender alarm-trigger) (Receiver fault-agent)
(Msg_Type request) (Performative alarm) (Request_Action DISPLAY) (Gen_Params routing)"")
(shared-manager-buffer)
==> Focus Agent-Manager from MAIN
FIRE    1 agent-msgs: [MAIN::shared-memory]
==> Focus FAULT-Agent from Agent-Manager
FIRE    2 activation-rule: [MAIN::shared-memory]
==> f-1     (ALARM routing)
FIRE    3 p-schema_Alarm-routing: f-1
<== f-1     (ALARM routing)


ALARM DETECTED: Node is not routing properly.
==> f-2     (links ok)
==> f-3     (system ok)
==> f-4     (tables problem)
FIRE    4 p-schema_Fault_Correction_Routing: f-2,f-3,f-4
<== f-2     (links ok)
<== f-3     (system ok)
<== f-4     (tables problem)


DIAGNOSIS:  Links status ok
        System status ok
        Tables status problem

CORRECTION:  Re-configure node routing tables


==> Focus Agent-Manager from FAULT-Agent
<== Focus Agent-Manager to FAULT-Agent
<== Focus FAULT-Agent to Agent-Manager
<== Focus Agent-Manager to MAIN
<== Focus MAIN to Agent-Manager
<== Focus Agent-Manager to CONF-MNGMT-Agent
<== Focus CONF-MNGMT-Agent to NET-USAGE-Agent
<== Focus NET-USAGE-Agent to PERFORMANCE-Agent
<== Focus PERFORMANCE-Agent to FAULT-Agent
<== Focus FAULT-Agent to SECURITY-Agent
<== Focus SECURITY-Agent to MAIN
<== Focus MAIN
```

Source Code for the Fault Management Specialist Agent

```
;;;==========================================================================
;;; Fault Agent Specialist  module
;;;
;;;==========================================================================

(defmodule FAULT-Agent (import MAIN defclass SPECIALIST)
                       (import MAIN defclass MSG-CLASS)
                       (import MAIN defclass shared-memory)
                 (export defclass fault-specialist))

 (defclass FAULT-Agent::msg-frame (is-a MSG-CLASS))  ;;;message frames


 (defclass FAULT-Agent::fault-specialist (is-a SPECIALIST)
  (role concrete)
  (pattern-match reactive)

  (slot agent-id                          ;;;agent-id
        (create-accessor read-write))
  (slot current-request
        (create-accessor read-write))
  (multislot incomplete-frames-buf
            (create-accessor read-write))

  (message-handler Incoming-msg-Daemon)
  (message-handler Outgoing-msg-Daemon)
  (message-handler Task-Daemon)
 )       ;;;End of class

;;;;-----------------------------------------

(defglobal FAULT-Agent
 ?*frame* = nil
 ?*frame-list* = (create$)
 ?*new-frame-list* = (create$))



;;;=======================================================================
;;;Outgoing Message Daemon
;;;
;;;=======================================================================

(defmessage-handler FAULT-Agent::fault-specialist Outgoing-msg-Daemon ()
 (progn$ (?msg ?self:outgoing-msg-buf)
        (bind ?msg-string (send ?self convert-msg-frame-to-string ?msg))

        (bind ?list (str-cat "node-manager " (implode$ (create$ ?msg-string))))

        (focus Agent-Manager)
        (focus FAULT-Agent)
```

```
            (focus MAIN)
            (slot-insert$ [MAIN::shared-memory] shared-manager-buffer 1 ?list)
            (focus FAULT-Agent)

            (slot-delete$ ?self outgoing-msg-buf 1 1)
            (send ?msg delete))
   (return))



;;;==================================================================
;;;Strategy-goal-Daemon
;;;
;;;==================================================================

(defmessage-handler FAULT-Agent::fault-specialist Strategy-goal-Daemon ()
  ;;;c-schema develop goal and plan to achieve goal
  ;;;remove msg to be processed from buffer and update history

  ;;;process any incoming messages
   (bind ?msg (nth$ 1 ?self:incoming-msg-buf)) ;;msg from incom.msg.buf

   (if (stringp ?msg)
      then
        (bind ?message (send ?self convert-string-to-msg-frame ?msg msg-frame))
      else (bind ?message ?msg))

   (if (eq (send ?message get-Msg_Type) response)
      then
       (printout t "Resp. rec." crlf))


   (bind ?*frame* ?message)

   (slot-delete$ ?self incoming-msg-buf 1 1)
   (dynamic-put current-request ?message)

)


;;;*******************************************************************

(defmessage-handler FAULT-Agent::fault-specialist Strategy-goal-Daemon
 after ()
 ;;;develop goals to accomplish the request
 ;;;second part of c-schema


(if (eq (send ?*frame* get-Performative) alarm)
   then
        (bind ?param (nth$ 1 (send ?*frame* get-Gen_Params)))
        (if (eq ?param routing)
          then (assert (ALARM routing))
```

```
      )
     (run)
   )

 (return)
)


;;;============================================================================
;;;  get-local-msgs
;;;
;;;     checks the shared-msg-buffer to see if any of the mesgs
;;;     present are for me
;;;
;;;============================================================================

(deffunction FAULT-Agent::get-local-msgs ()
 (bind ?ret-val FALSE)

 (progn$ (?message (send [MAIN::shared-memory] get-shared-msg-buffer))
          (bind ?msg (explode$ ?message))
          (bind ?to-agent (nth$ 1 ?msg))
          (if (eq ?to-agent fault-agent)
            then
             (slot-insert$ [fault-agent] incoming-msg-buf 1 (nth$ 2 ?msg))
                (slot-delete$ [MAIN::shared-memory] shared-msg-buffer
                                 ?message-index ?message-index)
                (bind ?ret-val TRUE)
                (break)
          )
   )
 (return ?ret-val)
)


;;;============================================================================
(deffunction FAULT-Agent::check-links ()
 (return ok)
)

;;;============================================================================
(deffunction FAULT-Agent::check-sys ()
 (return ok)
)

;;;============================================================================
(deffunction FAULT-Agent::check-tables ()
 (return problem)
)

;;;============================================================================
(deffunction FAULT-Agent::fault-diagnosis (?alarm)

 (if (eq ?alarm routing)
```

```
            then
              ;;check links
              (bind ?links (check-links))
              ;;check system
              (bind ?sys (check-sys))
              ;;check tables
              (bind ?tables (check-tables))

              ;;;assert facts into rule base
              (assert (links ?links))
              (assert (system ?sys))
              (assert (tables ?tables))
    )

   (run)
  )

;;;=========================================================================
;;;rule base for generic agent
;;;
;;;=========================================================================

 (defrule FAULT-Agent::activation-rule
  (object
         (shared-msg-buffer ?))
  =>
  (focus FAULT-Agent)
  (bind ?val (get-local-msgs))
  (if (eq ?val TRUE)
     then
       (send [fault-agent] Strategy-goal-Daemon)
   )
  (run)
 )

;;;-----------------------------------------------

(defrule FAULT-Agent::p-schema_Alarm-routing ""
 ?x <- (ALARM routing)
 =>
 (retract ?x)

 (printout t crlf crlf "ALARM DETECTED: Node is not routing properly." crlf)
 (fault-diagnosis routing)

 (run)
)

;;;------------------------------------------------------------------------
(defrule FAULT-Agent::p-schema_Fault_Correction_Routing ""
 ?x <- (links ok)
 ?y <- (system ok)
 ?z <- (tables problem)
 =>
```

```
 (retract ?x)
 (retract ?y)
 (retract ?z)

 ;;;problem is with routing tables
 ;;;best solution is to reconfigure the tables
 (printout t crlf crlf)
 (printout t "DIAGNOSIS:  Links status ok" crlf
               "        System status ok" crlf
          "        Tables status problem" crlf crlf)

 (printout t "CORRECTION:  Re-configure node routing tables" crlf)
 (printout t crlf crlf)


 (focus Agent-Manager)
 (run)

)
;;;------------------------------------------------------------------------


(defrule FAULT-Agent::p-schema_Route ""
 ?x <- (route request)
 ?y <- (activate route)
 ?z <- (Frame Validated)
 =>
 (retract ?x)
 (retract ?y)
 (retract ?z)

 (bind ?request (send [fault-agent] get-current-request))

 (if (neq gcmd (nth$ 1 (send ?*frame* get-Service)))
   then
    ;;;generate a response/request
    (send ?*frame* put-Performative gns-results)
        (send ?*frame* put-Sender fault-agent)
        (send ?*frame* put-Receiver *routing*)
        (send ?*frame* put-Msg_Type request)

        (slot-insert$ [fault-agent] outgoing-msg-buf 1 ?*frame*)

   else  ;;;send to agent coord to analyze

    (send ?*frame* put-Performative analyze)
        (send ?*frame* put-Sender fault-agent)
        (send ?*frame* put-Receiver *routing*)
        (send ?*frame* put-Msg_Type request)

        (slot-insert$ [fault-agent] outgoing-msg-buf 1 ?*frame*))
```

```
 ;;;formulates a general response back to coordinator
 (send [fault-agent] Outgoing-msg-Daemon)
 (focus Agent-Manager)
 (run)
)


;;;===================================================================
;;; convert-msg-frame-to-string
;;;
;;; Returns a message string composed of all the slots of the class
;;; instance passed in.
;;;
;;;===================================================================

(defmessage-handler FAULT-Agent::fault-specialist convert-msg-frame-to-string (?instance)



 (bind ?agent-msg (create$))
 (bind ?msg-str "")
 (bind ?class (type ?instance))

 (bind ?slot-list (class-slots ?class inherit))

 (progn$ (?slot ?slot-list)
        (bind ?command (eval (str-cat get- ?slot)))
        (bind ?value (send ?instance ?command))

        (if (multifieldp ?value)
          then
           (bind ?value (implode$ (create$ ?value)))
          else     /* single slot */
               (if (stringp ?value)
                 then
                  (bind ?tmp (explode$ ?value))
                  (if (> (length$ ?tmp) 1)
                        then
                         (bind ?value (implode$ (create$ ?value)))
                      )
               )
        )

        (if (and (neq ?value "") (neq ?value nil))
          then
           (bind ?agent-msg
                (create$ ?agent-msg
                    (str-cat "(" ?slot " " ?value ")")))
        )


  ) ;;end progn

 (progn$ (?slot ?agent-msg)
```

```
            (bind ?msg-str (str-cat ?msg-str " " ?slot))
            )

  (return ?msg-str)
 )


;;;=====================================================================
;;; convert-string-to-msg-frame
;;;
;;; Returns an instance of type ?class with the slots from ?agent-msg
;;; filled in.
;;;
;;; NOTES:
;;;    WARNING - Class needs to already exist
;;;
;;;=====================================================================

(defmessage-handler FAULT-Agent::fault-specialist convert-string-to-msg-frame
 (?agent-msg ?class)

 (bind ?instance
        (eval (str-cat "(make-instance [MSG-" (gensym*) "] of "
                       ?class " " ?agent-msg ")")))
 (return ?instance)
 )



;;;=====================================================================
;;; Define frame's id
;;;=====================================================================

(defmessage-handler FAULT-Agent::fault-specialist tag-frame ()
 (bind ?frame-id (gensym*))
 (return ?frame-id))



;;;=====================================================================
;;; Define msg id
;;;=====================================================================

(defmessage-handler FAULT-Agent::fault-specialist tag-msg ()
 (set-current-module Agent-Manager)

 (system "hostname > /tmp/msg-tagging")
 (system "date +%D-%H:%M:%S >> /tmp/msg-tagging")
 (open "/tmp/msg-tagging" msg-file "r")
 (bind ?msg-tag (read msg-file))
 (bind ?msg-tag2 (read msg-file))
 (close msg-file)
 (bind ?msg-id (sym-cat "#" ?msg-tag "-"?msg-tag2 "#"))
 (remove /tmp/msg-tagging)
```

```
(return ?msg-id))
```

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13. ABSTRACT ***(Maximum 200 words)***

This report presents the results of our research on Earth-Mars Telecommunications and Information Management System (TIMS) network modeling and unattended network operations. This research is a follow-on study to prior activities reported in the documents referenced in paragraph 1.1. The primary focus of our research is to investigate the feasibility of the TIMS architecture, which links the Earth-based Mars Operations Control Center, Science Data Processing Facility, Mars Network Management Center, and the Deep Space Network of antennae to the relay satellites and other communication network elements based in the Mars region. The investigation was enhanced by developing Build 3 of the TIMS network modeling and simulation model. The results of several "what-if" scenarios are reported along with reports on upgraded antenna visibility determination software and unattended network management prototype.

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